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PROTECTION OF AIRCRAFT FLUID SYSTEMS

J. M. Metcalf, R. E. Roberts, S. D. Bridgman

LTV Aerospace Corporation

TECHNICAL REPORT AFML-TR-68-125

May 1968

AIR FORCE MATERIALS LABORATORY
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

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J. M. Metcalf, R. E. Roberts, S. D. Bridgman

FOREWORD

This report was prepared by LTV Aerospace Corporation, Vought Aeronautics Division as a part of the research and development program under Air Force Contract No. F33615-67-C-1673, Project No. 7381, "Materials Application," Task No. 738108, "Application of Materials and Processes for Limited War Support." The program was administered and monitored by the Air Force Systems Command, Directorate of Laboratories, Air Force Materials Laboratory (MAAE). Mr. Philip A. House was the Technical Monitor. The program was initiated 1 May 1967 and continued through 31 March 1968.

The principal contributors to the research and this report were Messrs. John M. Metcalf and Ralph E. Roberts of the Power Plant Installation Design Group, Product Design Department, and Messrs. Stanley D. Bridgman and Gean O. Clark of the Systems Test Group, Structures and Systems Laboratories. The project engineer was Mr. H. E. Reynolds, Applied Research and Development Section.

Acknowledgment is made to the various materials and aircraft manufacturers, research laboratories and government organizations listed in Table I of Appendix E for their responses to the survey which assisted in the establishment of the foundation of this program.

This report was submitted by the authors on 19 April 1968. This report contains no classified information extracted from other classified documents.

This technical report has been reviewed and is approved.

Albert Olevitch
ALBERT OLEVITCH, Chief
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ABSTRACT

This report describes the work done in a program to investigate available methods of protection of aircraft fluid systems from ballistic damage. Primary emphasis in this study was placed upon the protection of aircraft fuel tanks through the use of self-sealing fuel tank materials. A number of protection materials were selected and subjected to gunfire testing with .30 and .50 caliber projectiles. Significant conclusions of the program are as follows:

a. Internal tank pressures reduce probability of sealing.

b. Hydraulic ram pressure induces significant structural damage, thereby reducing probability of sealing exit wounds.

c. Petaling of skins in intimate contact with tank material had little or no effect on sealing of entrance wounds.

d. Existing materials can provide satisfactory protection when properly utilized.

e. Several new materials were tested which show evidence of potential application, particularly backing boards.

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SECTION I

INTRODUCTION

1. BACKGROUND

There is, from a practical standpoint, no design possible that would prevent penetration of aircraft fluid systems by gunfire because of the extreme weight penalties imposed on the airplane. Therefore, it is necessary to accept the penetration as a fact and to take measures to minimize fuel loss, fire hazard, and structural failure to a point that a high degree of safety can be built into future aircraft.

The objective of this study program was to evaluate the available methods for reducing the vulnerability of aircraft fluid systems to damage from small arms gunfire, with primary emphasis on fuel tank protection.

2. TECHNICAL APPROACH

The study was divided into three separate parts. The first part of the study was a survey of all manufacturers, suppliers and users of self-sealing tank materials and backing board and of airframe and/or military users of such material. This survey was performed to ascertain the industry "state-of-the-art" as to new and experimental materials under development and established and qualified materials still being manufactured, as well as to provide a wide choice of materials that could be chosen for testing in this study. In addition to contacts made with manufacturers and users, a search of published literature was made and a bibliography prepared.

Since deformation of the aircraft skin by the ballistic projectile, "petaling", was thought to have pronounced effects on the performance of bullet-sealing fuel tanks, the second part of the study was a series of "dry skin gunfire" tests to study petal height and roll, skin coring, etc. of various skin alloys and thicknesses when caliber .30 and .50 rounds, both straight through and tumbled, were fired into them. Table III is a summary of the skins used in the gunfire petaling tests.

After completing the dry skin firing, the last part of this study, wet tank gunfire tests, was performed. This part consisted of gunfiring some composite type panels and combinations of backing board and self-sealing material panels which were attached to the ends of a fuel test tank filled three-fourths full of JP-4 fuel. All rounds were fired into tank below the fuel level. The effects of the following parameters were examined in this phase of the study .

- o Internal tank pressure - 0 to 2 psig
- o Fuselage skin to tank wall gaps - 0 to 1.50 inches
- o Projectile size - caliber - .30 or .50
- o Entry mode - straight-through or tumbled

- With and without reticulated foam or perforated plastic spheres (whiffle balls)

- Armor piercing or Armor piercing incendiary ammunition

All of the parameters examined are related to developing a more effective "defensive" design for aircraft fuel systems.

SECTION II

SUMMARY

An industry survey was made for the purpose of determining what materials and techniques might be applicable to protection of aircraft fluid system. A total of thirty-six airframe manufacturers, material manufacturers and defense installations were contacted. Based upon the information received and with the continued cooperation of interested members of industry, the plans for the gunfire tests were made.

The dry skin gunfire tests were conceived as a quick method to examine the "petaling" characteristics of various metal alloys which are used as aircraft skins. Twenty-eight rounds of caliber .50 armor piercing and thirty-one rounds of caliber .30 armor piercing were fired into twenty-four skin panels made from three aluminum alloys and AMS4901 titanium. Section V is a detail dissertation of the results of this part of the test.

The industry survey to find test materials and the "dry skin" gunfire tests were preliminaries to the larger wet tank gunfire tests. The broad base of the wet tank gunfire tests encompassed the examination of some 12 backing boards, 9 self-sealing material combinations, and 3 defense composites with eight parameters varied during the gunfire testing.

The applied internal pressure up to 2 psi had a marked influence on the sealing properties of all materials tested. In several instances, sealing was not achieved in the time allotted in MIL-T-5578 while a head pressure of 2 psig was on the test tank. However, upon release of pressure, immediate seals occurred. This seemed to be independent of the caliber or entry mode of the round fired.

The skin to backing board gap was varied from 1.50 to 0 inch in an effort to determine the effect of skin petaling holding open the wounds in the backing board and self-sealing material. Several attempts were made to demonstrate this "petaling" influence but the results were not conclusive. Similarly, changes in skin thickness and alloy seemed to have no effect upon the test results. Sealing on entrance and exit penetrations occurred as well with zero gap as with clearances up to 1.25 inch. Zero gap on exit penetrations did result in catastrophic damage to the exit skin panel because of ram pressures developed within the tank. Except when the skin gap was zero, the skin panels were unsupported.

All materials were gunfired with the caliber ordnance recommended by the manufacturer. Selected combinations were also shot with higher caliber ordnance to see if the material would perform beyond its recommended protection level. Two projectile entry modes were examined, straight-through and tumbled. True to what was observed in the dry skin firing, the tumbled rounds caused more structural damage and resulted in poorer sealing performance than the straight-through shots. No "pulled powder charge" rounds were fired in the wet tank gunfiring with only one exception and it was inconsequential. The incendiary rounds were fired straight-in only. However, because of the presence of the striker plate, about 18 inches forward of the front panel, the incendiary rounds impacted in a partial tumbled mode. The caliber .30 incendiary rounds

apparently did no more structural damage than the regular AP ammunition, but did always carry the probability of fire.

A reticulated polyurethane foam was installed in the test cell as a fire suppressant when incendiary rounds were fired. The foam was also used in some installations for the regular armor piercing rounds. The foam was found to be an excellent fire suppressant, to have no detectable effect on sealing, and appeared to decrease the destructive force of the hydraulic ram pressure.

Another parameter examined was the action of perforated hollow plastic spheres (whiffle balls) installed in the test tank. It was believed that when a self-sealing material was punctured that these balls, being inside the tank, would act as an internal brace allowing only minimum tank wall deformation, thus aiding in the sealing process. Minimum testing with whiffle balls was conducted, and on this basis, no definite conclusions could be drawn as to the effect of their presence. This test by itself showed that the balls did not aid in the sealing action of the tank with or without an applied pressure of 2 psi. The balls in the path of the projectile showed various states of destruction ranging from surface cracks to complete disintegration.

Normal variations in atmospheric and fuel temperature and fuel quantity occurred but had no noticeable effect on the test results. All rounds were fired into a 3/4 full tank containing approximately 55 gallons.

There was a noticeable difference in the overall destructive effect of straight-in and tumbled rounds on entrance panels. Forty-nine, or 91 percent of the straight-through entrances sealed satisfactorily while only about 68 percent of the tumbled entrance wounds sealed. No matter what the mode of entry, all rounds which exited from the tank did so in the tumbled mode. As a result of the tumbled exit mode and hydraulic ram pressures, the exit panels and backing board consistently suffered more damage than the entrance panels and backing board. This point is discussed thoroughly in Section VI for wet tank gunfire tests.

SECTION III

RECOMMENDATIONS

1. GENERAL

The results of this study indicate the following courses of action in design for decreasing the vulnerability of aircraft fuel tanks from small arms fire.

a. That the structural support for self-sealing fuel tanks be such that the structure can "work elastically" and not rupture under the hydraulic ram pressure waves.

b. That future fuel tank installations favor a quality backing board and a marginal self-sealing cell material combination over a quality self-sealing cell material and marginal backing board combination, if compromise is required.

c. That internal tank pressures be made as low as possible, preferably zero.

d. That the installation of a fire suppressant foam in fuel cells be made a basic requirement as a safeguard against internal explosion and fire.

2. ADDITIONAL TESTING

The results of this study indicate further testing is needed on the following items:

a. Hydraulic ram pressure measurement, control, effect, and dissipation.

b. Zero clearance between skin and backing board to determine the effect on the sealing capabilities of tank materials.

c. Self-sealing materials under higher pressures since many aircraft fuel systems operate at pressures greater than 2 psi.

3. MATERIALS CONSIDERATIONS

The results of this program indicate that material selection for future design should consider, as a minimum, the following points:

a. Prior to use, the backing board should be subjected to extensive ballistic tests with the self-sealing tank in intimate contact to determine resistance to hydraulic ram pressure.

b. The backing board/self-sealing material combination should be tested in simulated aircraft structure as early as possible to determine capability of overall protection system for resisting hydraulic ram pressures.

c. If at all possible, a fuselage skin of a more ductile material be chosen rather than 7075-T6 aluminum or a titanium alloy. This will eliminate practically all fire-flashes on entrance and thus decrease the probability of fire and explosion.

4. SPECIFICATIONS

In conjunction with the above recommendations, the following specification changes should be made:

a. Revise testing procedures contained in military specification MIL-P-8045 for backing boards to include suitable ballistic testing to ensure material performance in installed aircraft.

b. Revise Phase I test procedures in military specification MIL-T-5578 for self-sealing fuel tanks to include simulated structure in early tests in order that a more realistic evaluation of test results and prediction of installed performance may be obtained.

c. Prepare an installation specification to define the overall design objectives, and prescribe the necessary testing of combinations of materials to arrive at optimum self-sealing fuel tank systems.

SECTION IV

INDUSTRY SURVEY

The initial phase of this investigation consisted of an industry survey of manufacturers and users of self-sealing tank materials and backing boards. The survey was performed to obtain information on all compositions and backing boards that may be suitable for use in aircraft. The survey included materials currently in use and materials under development which showed promise of advancing the state-of-the-art for the protection of aircraft fluid systems from ballistic damage.

1. DATA QUESTIONNAIRE

The means chosen for collecting the desired data was a questionnaire which was sent to manufacturers of all known self-sealing materials and backing boards. This questionnaire, mailed with a letter of explanation, Appendix A, requested the Vendors to submit information on all compositions and part numbers of their products that would qualify for testing as an aircraft fluid system protection product.

A second questionnaire, mailed with a letter of explanation, Appendix B, was directed to all airframe manufacturers. This document requested the airframe manufacturer to provide information on the methods of protection and materials employed for the protection of aircraft fluid systems from ballistic damage.

Both questionnaires were mailed to Armed Services representatives, research and defense installations requesting information on the current testing in the field of aircraft fluid systems protection and/or any related field.

The technical library at VAD was requested to make a literature search on the subject of vulnerability of self-sealing fuel cells, etc. This bibliography is presented in Appendix C. In addition to the above sources of information, reports and/or information were loaned and recommended for study by the contracting agency, Federal agencies, and commercial vendors. A list of the associated reports studied is given in Appendix D.

2. DATA SOURCES

Table E-I of Appendix E is a complete list of all airframe and materials manufacturers and research and defense installations contacted during the industry survey. Each data source which indicated the availability of material of particular significance was contacted directly, either by telephone or by personal visit. The majority of the group queried exhibited a high degree of cooperation.

Table E-I presents relevant information, in brief form, gathered from the listed sources. Tables E-II and E-III list candidate materials and pertinent physical data for each. A detailed description of the construction of the candidate materials is presented in paragraph 3 of this section.

3. CANDIDATE MATERIALS

During this survey, information was received on a number of candidate materials for protection of aircraft fuel tanks. These materials can be divided into the following categories: backing board materials; self-sealing tank materials; self-sealing coatings for metal or integral tanks; and special materials for reduction of hazards from fire and/or explosion.

a. Backing Board Materials

(1) Conolite Corp., Carpentersville, Illinois, manufactures three backing board compositions in thicknesses of 26, 33 and 60 mils. This range covers the caliber .30 and .50 protection levels established by MIL-P-8045. These three compositions have continuous filament reinforcements of high quality glass cloth, except for a center ply of B60RK2W, which is cotton. The laminating material is a reinforced polyester resin which meets the requirements of MIL-P-8045. This composition is a good example of a proven material.

(2) Goodyear Aerospace, Litchfield Park, Arizona, manufactures two backing board compositions. ARM-018 board is a proven product which exceeds the requirements of MIL-P-8045. Even though it has a three-ply thickness of 0.070 inch, the unit weight of 0.35 pounds per square foot is acceptable for aircraft use. This plastic laminate is a flexible material made by using a woven ballistic resistant nylon impregnated with a urethane resin. ARM 1800 is the standard ARM 018 construction with a thin sheet of tear resistant urethane applied to the outside surfaces. This additional layer supplies a good slipping surface for any material in contact with it as well as offering protection from shrapnel particles from the skin when a hit is incurred. This feature is particularly desirable in zero clearance skin gap installations.

(3) Air Logistics Corporation, Pasadena, California, manufactures a wide variety of backing board constructions. Much information concerning the compositions and recommendations for specific applications of their materials is available. The basic board, series 700 SI, is a pressure molded, multi-ply, fiberglass epoxy laminate with special facings for particular uses. Each layer is unidirectional fiberglass and molded at an angle to its adjacent layers. Normally the board is faced on both sides with Nomex paper or a polyurethane coating. If bonding to some other material is required, one side is left uncoated. Heavy, medium and light weight boards are available to cover both caliber .50 and .60 protection levels. This composition is currently in the process of being tested to MIL-P-8045.

(4) The M. C. Gill Corporation, El Monte, California, manufactures two material compositions, Gillfab 1068 and 1075, suitable for use. These materials have seen widespread use as baggage compartment liners and fuel system backing board replacements, but had not had a ballistics test as demanding as that employed in this program. The 1075 composition meets the requirements for oil tank backing board per MIL-P-8045 Class II, Type I. Both products are fiberglass/polyester thermo-cured laminates of good mechanical

strength within an acceptable temperature range. The chief components of the laminates are a fiberglass mat, filler, and resin which can be fabricated accurately to almost any desired thickness.

The 1075 composition has a desirable flame resistant feature which is not present in the 1068. Because of this flame resistant feature, the 1075 composition holds good mechanical strength to 260°F instead of 160°F, the strength temperature level for 1068. Suppliers of raw materials for both compositions are the Pittsburg-Plate Glass Co. for the mat and Hooker and InterCity Chemical Company for the resins. In the final product, there exists about a 50% resin to fiberglass ratio with the clay filler added to complete the final construction.

(5) Firestone Coated Fabrics Co., Akron, Ohio, produces two boards, Fl-41 and B-2. The structural make-up of these boards is fiberglass with a polyester binder. Both compositions meet the requirements of MIL-P-8045 and carry a caliber .50 protection level rating. The Fl-41 board is 0.080 inch thick and weighs 0.41 pounds per square foot. The B-2 construction is a variation of the Fl-41 created by applying a urethane spray coating as a finishing coat while the finishing coat on the Fl-41 is an epoxy resin. Pre-production approval was granted the B-2 material on the basis of its similarity to Fl-41.

b. Self-Sealing Tank Materials

(1) UniRoyal Inc. of Mishawaka, Indiana, has manufactured a variety of self-sealing tank constructions in both .50 and .30 caliber capability, but only four are in current usage: US 173, US 182, US 179 and US 180. Variations of these self-sealing constructions are also used in combination with standard bladder constructions.

US 173 is UniRoyal's standard self-sealing fuel cell construction and many other self-sealing constructions are adaptations of US 173 to special customer requirements. US 173 is qualified to gunfire requirements of MIL-T-5578 Level A (Caliber .50) standards and is a heavy material (weighing 1.15 lbs/sq ft) and is 0.217 inch thick. US 173 construction from the fuel side out consists of the following plies: calendered rubber liner, barrier, natural rubber sealant, tire cord, natural rubber sealant, two tire cords and a coat of nitrile rubber. The tire cord plies are nylon and the other layers are nitrile rubber or coated with nitrile rubber to be compatible with the fuel used. US 182 is a caliber .50 protection level material developed for Vought Aeronautics Division of LTV Aerospace Corp. for use in the A-7A aircraft. It is similar in layer make-up to US 173 with two exceptions. The calendered rubber liner was replaced by a thin non-wicking fabric (same as the liner in US-566RL non-self-sealing construction) and the sealant plies were reduced in thickness to achieve desired weight and wall thickness decreases. The weight of US 182 is 0.86 lbs/ft^2 and the thickness is 0.173 inch. Because of the relatively thinner construction of US 182, this material would not pass the rigorous Phase I gunfire tests defined in MIL-T-5578. Modified Phase I testing was performed using a special honeycomb and backing board support, Conolite board B33FG1W, which was installed in the A-7A aircraft to compensate for this condition. When installed with the simulated aircraft structure, US 182 successfully completed Phase I, caliber .50 level, per MIL-T-5578.

For caliber .30 protection level, US 179 and US 180 are available. Both of the constructions are in active service and have satisfied the requirements of MIL-T-5578. US 179 is a medium weight construction consisting of a rubber liner, a nylon barrier, a single ply of sealant, and two cord plies. Weight saving over caliber .50 material is a resul of fewer and thinner plies. US 179 weighs 0.64 lb/ft^2 and is 0.122 inch thick. US 179 is now in use in the Bell Helicopter UH-1D and Boeing Vertol CH-47. US 180 is basically the same material layout as US 179, differing only in the inner liner. The liner in US 180 is a rubber coated fabric instead of a calendered rubber liner, thus giving this construction an extended shelf life and resistance to in-service aging. Due to this liner change, the US 180 composition weights 0.49 lbs/ft^2 and is 0.12 inch thick. The increased wall flexibility of US 180 permits this construction to be more readily adaptable to retrofit into previously non-self-sealing fuel cavities. This construction is now in use in Bell Helicopter AH-1G, North American OV-10, Fairchild Hiller FH-1100, and Hughes LOH.

(2) Goodyear Tire and Rubber Company of Akron, Ohio, manufactures three basic self-sealing tank compositions and many variations. Two of the basic constructions, FTL-13 and FTL 11-3, are proven materials while the third, DX 325, is a new construction. (Since the beginning of the survey, the DX325 material has been reidentified as FTL-17.)

The Goodyear FTL-13 is a caliber .30 protection level material made up of the following four plies from the fuel side out: Buna-N, sealant, nylon fabric, and an outside nylon fabric which is resistant to aromatic fuels. This construction is nominally 0.10 inch thick and weighs 0.543 lbs/sq ft. This construction is now in use on Sikorsky S-64, HH-3C, and S-61 helicopters and has been qualified to protection level (B) per MIL-T-5578 since 1964.

The FTL-11-3 construction is Goodyear's basic .50 caliber construction. Many variations of this basic number have been manufactured by Goodyear for special applications and to customer requirements. This basic construction has a long history of performance and use on such aircraft as Boeing B-47, Republic F-84F, and McDonnell F3H and F-101. This construction was first qualified for .50 protection level (A) of MIL-T-5578 as early as 1952. Because of its protection level, it is a heavy (1.20 lbs/sq ft) material of 0.247 inch thickness composed of the following seven layers from the fuel side out: Buna-N, rubber sealant, nylon cord (vertical), nylon cord (horizontal), rubber sealant, nylon cord (45° right), and outside nylon cord (45° left), coated to be resistant to aromatic fuels.

The DX325 is a new construction developed by Goodyear. This construction from the fuel side out is made up of the following plies: Buna-N sealant, nylon fabric, sealant, 2 plies of nylon fabric with the outside coated for resistance to aromatic fuels. This is a caliber .50 protection level material that as yet has not been qualified to MIL-T-5578 but has the composition for this protection level. The build up thickness of 0.170 inch and it weighs 0.855 pounds per square foot.

(3) Firestone Coated Fabrics Co., Akron, Ohio, manufactures three basic self-sealing constructions, 1146, 1316-3, and 1451, which are qualified per specification MIL-T-5578. The 1146 construction has been qualified to protection level A, caliber .50 and 20 mm, since 1953 and has been installed in Douglas A-4E and TA-4E aircraft since qualification tests. The construction weighs 1.31 lbs/sq ft and has a nominal thickness of 0.24 inch. The 1146 construction is made up as follows from the fuel side out: buna-gum inner ply, nylon fuel barrier, sealant, nylon fabric, sealant, 2 cord plies and an outer layer of buna cement. The 1316-3 construction manufactured by Firestone Coated Fabrics Co. is a caliber .30 protection level material. This is a comparatively heavy (1.01 lbs/sq ft) material for a nominal thickness of 0.21 inch. This material is presently used in hurricane boats and U.S. Army ERDL air boats, attesting to its serviceability. The makeup of the 1316-3 construction from the fuel side out is as follows: inner ply of nylon fabric, nylon barrier, sealant, 2 layers of nylon fabric, and a gum coating. The 1451 construction is a lightweight .30 caliber material (0.57 lbs/sq ft) 0.118 inch thick. The makeup of 1451 from the fuel side out is as follows: bune-gum inner ply, nylon fuel barrier, sealant, nylon fabric and an outer ply of polyurethane gum.

(4) Goodyear Aerospace Corporation of Litchfield Park, Arizona, is in the process of developing a self-sealing fuel tank construction using liquid coagulants suspended within the walls of the tank. When the tank is penetrated by a projectile, the coagulant flows into the resulting hole and forms a plug. This material, known as ARM 024, weighs 1.00 lbs/sq ft and is approximately 0.25 inch thick. The material is semi-rigid because of its construction features and requires that the liquid coagulant be added to the tank walls after the tank is installed in the aircraft. The construction has been shown by test to have the capability of sealing not only normal .50 caliber projectile holes but also larger and irregularly shaped penetrations. Because this material is still under development, exact details of the construction are not currently available.

c. Protective Materials for Metal and/or Integral Tanks

(1) Air Logistics, Pasadena, California, manufactures three experimental "defense composites". Vendor parts numbered 114509-102, a one piece assembly; 114509-217, a two piece assembly; and 114509-304, a one piece assembly, are the special configurations considered as most applicable. The construction of 114509-102 and -217 are adjoining layers of backing board, sealant rubber, and backing board. On the -217 composite, one backing board is not bonded to the sealing rubber. The backing board is also not finished with a fuel resistant coating. Protection level attributed to these composites has not been stated by the vendor. These materials are designed to serve as cavity liners for ferry fuel tanks and are not in contact with fuel except when penetrated by a projectile. Air Logistics defense composite 114509-304 was designed purposefully as a protective device for application to the exterior surface of integral fuel tanks, having the sealant rubber bonded to the aluminum skin and then the backing board bonded to the raw rubber.

(2) Goodyear Tire and Rubber Company, Akron, Ohio, manufactures a self-sealing coating for metal fuel lines and tanks known as FLC-1. The FLC-1 coating consists of a 0.125 inch thickness of rigid cast polyurethane

("Vithane") bonded to the metal, a 0.125 inch layer of sealant material, a reinforcing fabric, and a final layer of 0.125 inch thick Vithane. The coating weighs approximately 2.0 lbs/sq ft.

(3) Minnesota Mining and Mfg. Company manufactures a compound with potential application, HC-1101 (L-2216). This compound was arbitrarily classified as a "defense composite" for convenience of reporting only. In a sheet thickness of 0.30 inches, this material weighs 1.53 lbs/sq ft. This material is rigid and is a polymeric amine cured with an epoxy resin, and as such could be used as an external coating material for integral fuel cells and fuel and oil transfer lines. In view of its development status, it has not been qualified to any military specification. The use of this material in aircraft may be inhibited by the weight and because the temperature range is $65^{\circ}F$ to $150^{\circ}F$ while the environmental temperature range of modern aircraft is somewhat higher.

d. Special Materials

(1) Firestone supplies a reticulated polyurethane foam, LAS-103ZF orange foam, for installation inside the fuel tanks to reduce the hazard of fire and/or explosion when the tank is penetrated by an ignition source such as an ignited incendiary projectile. This material is open celled and has a density of 1.86 lbs/ft^3 and a tensile strength of 25 lbs/sq in. The foam creates a dry volume loss of 3% of fuel tank volume. In addition, some fuel becomes unavailable for use due to the wetting action of the fuel upon the surface of the foam. The effectiveness of this material has been examined in numerous tests.

(2) Kent Manufacturing Company manufactures perforated hollow plastic spheres (whiffle balls) which may have application in reducing the hazard of fire and/or explosion. The presence of these balls, part number BTG-6, is believed to reduce the spray of fuel through the entrance and exit holes made by the projectile and also to assist in aligning the self-sealing tank material for better performance.

SECTION V

DRY SKIN PETALING TESTS

1. TEST OBJECTIVE

Dry skin gunfire tests were included in this program to provide information on the effect of gunfire on aircraft skins. It was believed that data obtained from the dry skin testing would be helpful in the design and sequencing of the wet tank gunfire tests to follow.

2. TECHNICAL APPROACH

To reduce the time required to perform these tests, VAD decided to use a test setup which would permit each projectile to pass through three separate skin panels, believing that the energy lost in penetrating each panel would not be detrimental to evaluation of the final results. The fixture designed to hold the skin panels to be tested is shown in Figure 1. Each setup consisted of three panels of the same alloy placed one behind another with a 3.62 inch air space between the skins. Three commonly used aluminum alloys, 2024-T3, 6061-T6, and 7075-T6 were tested. From front to rear the aluminum skin panel stock thicknesses were 0.025, 0.040 and 0.080 inches respectively. In addition to the aluminum alloys, AMS4901 titanium skin panels were also tested. The titanium panel stock thicknesses from front to rear were 0.028, 0.045, and 0.063 inches respectively. Each material was gunfired with six or more rounds of caliber .30 armor piercing ammunition. The rounds fired included at least one straight-through round and one tumbled round each for powder charges of 100, 70, and 50 percent by weight. Variations in powder charges were used to obtain reduced projectile velocities representative of penetrations at various ranges. Velocity measurements were made on each round fired to permit later correlation.

Identical setups of the same materials were then gunfired with six or more rounds of caliber .50 armor piercing ammunition. The rounds fired included at least one straight-through round and one tumbled round each for powder charges of 100, 85, and 50 percent by weight. Cotton wadding was used to replace removed powder in the reduced charge rounds.

The velocity of each projectile prior to impact was determined by calculation based on the time required for the projectile to pass through two screens placed 48 inches apart. The position of these screens in the path of the projectile is shown in Figure 2. Each screen was connected electrically to a Herter's Mark VII chronograph. The chronograph was actuated by the projectile breaking the circuit through the first screen and stopped by the projectile breaking the circuit through the second screen. The screens were located as near as possible to the target face to that the velocity calculated would be essentially the impact velocity. The elapsed time was recorded in microseconds and the velocity was then calculated as distance divided by time (4 feet/number of microseconds).

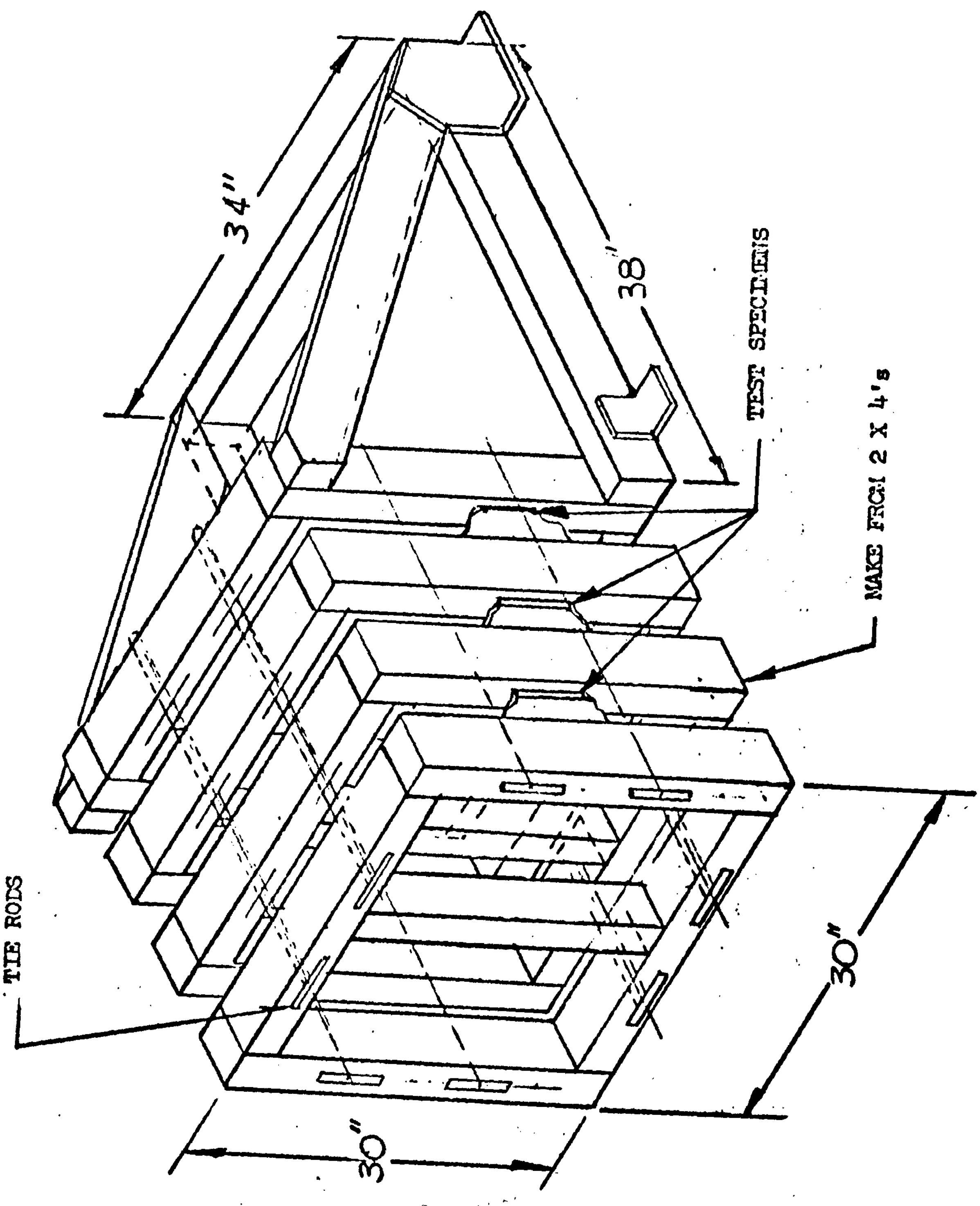
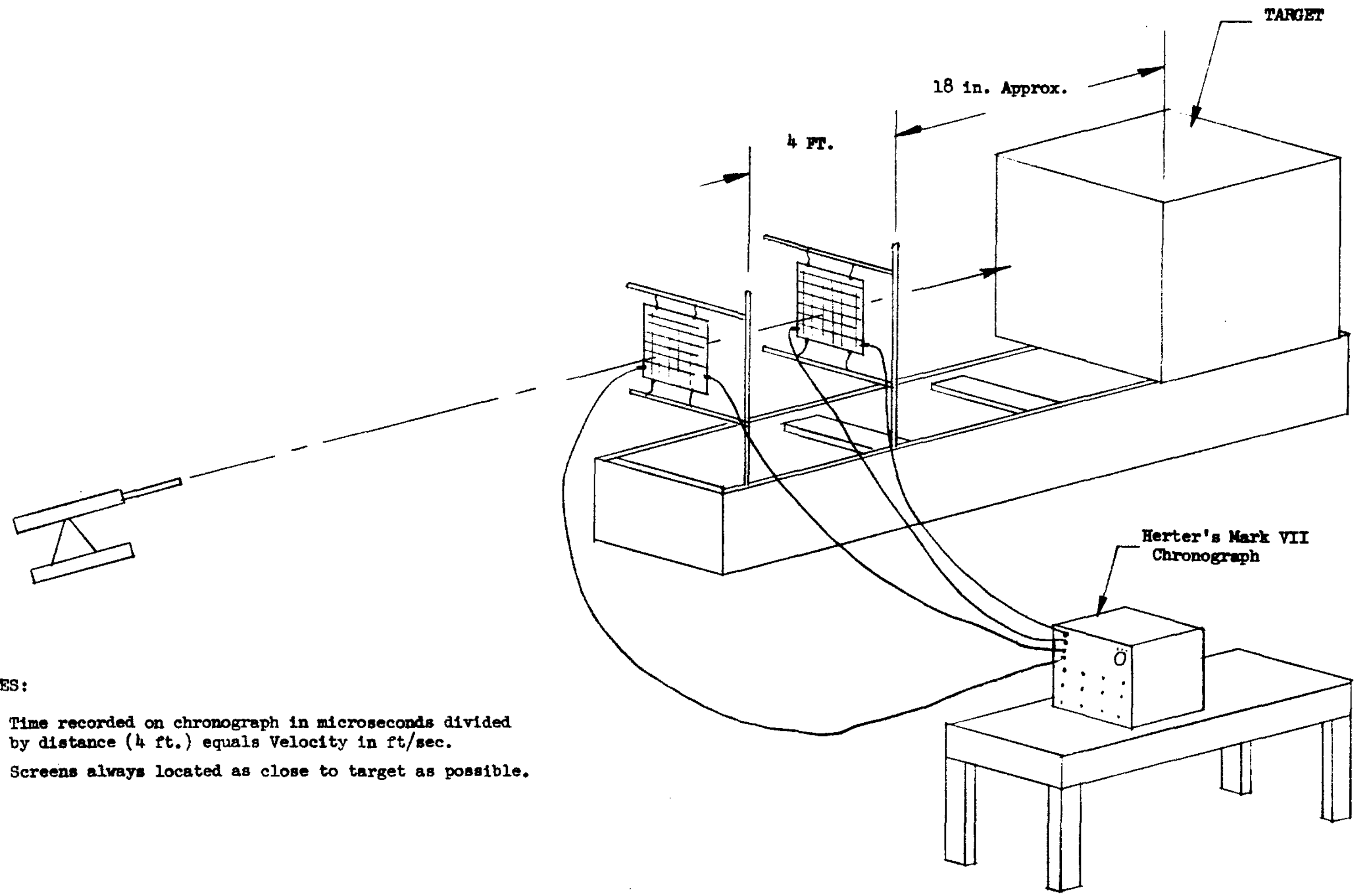


FIGURE 1

SKIN PETALING TEST FIXTURE



NOTES:

1. Time recorded on chronograph in microseconds divided by distance (4 ft.) equals Velocity in ft/sec.
2. Screens always located as close to target as possible.

FIGURE 2
PROJECTILE VELOCITY MEASUREMENT

3. GENERAL RESULTS

The dry skin gunfire sequence for the caliber .30 AP ordnance was completed with the following results:

CALIBER AND TYPE	POWDER CHARGE %	MODE OF ENTRY	NO. OF ROUNDS	VELOCITY		
				MAX. FT/S	MIN. FT/S	AVG. FT/S
.30 AP	100	Straight	3	2721	2685	2703
.30 AP	70	Straight	3	1951	1914	1929
.30 AP	50	Straight	3	1384	1370	1379
.30 AP	100	Tumbled	6	2614	2424	2550
.30 AP	70	Tumbled	2	1932	1896	1914
.30 AP	50	Tumbled	2	1356	1220	1288

These measured velocities include a ±14 feet per second error introduced by the electronics of the measuring device used. The consistency of the velocities verifies the fact that the test specimens received practically identical impacts.

An analysis of the petal heights created by caliber .30 AP straight-through rounds shows a general trend of increased petal height from the first (thinnest) to the last (thickest) panel, regardless of the impact velocity or panel material. This trend is also true for petals created by tumbled rounds through the AMS 4901 titanium panels. No apparent trend appears to exist for petal heights created by tumbled rounds through the aluminum panels. The inconsistency may be caused by the change of projectile energy from front to rear panels. The tumbled rounds had higher petals on the average than the straight through shots by approximately 20 percent for any one powder charge. The titanium panels had higher petals in both straight-through and tumbled than the aluminum alloy panels. The aluminum panels showed no trend among themselves for one alloy to have higher petals than another. Generally, the higher velocity projectiles have a greater tendency to core the metal where lower velocity projectiles tend to cause higher petaling.

At the same impact velocity, no correlation could be found between the various aluminum alloy types and the corresponding petal height, but the various alloys did exhibit a marked difference in the type of damage inflicted by the projectile. Almost every round, both straight-through and tumbled, that passed through the titanium or 7075-T6 aluminum alloy cored the skin panels, causing fragments of the panel to strike or pass through one or more of the panels behind the cored panel. Straight-through rounds in the other aluminum alloy skin panels did not normally produce coring, although tumbled rounds consistently did so. Many of the holes made by straight-through shots were somewhat smaller in diameter than the slug which passed through them. Most of these undersize holes appeared in the thinner first skins. It is surmised that when the rounds passed through the thinner skins, the heat transmitted to the skin in the immediate area of the hole probably allowed the skin to deform under impact more elastically. Then after the heat was dissipated to atmosphere after passage of the round, the hole in the skin panel contracted to a slightly smaller diameter.

The caliber .50 dry skin gunfire tests were identical to the caliber .30 except for the percent powder charges in the cartridges fired. To obtain the projectile velocities desired, powder charges of 100, 85, and 50 percent by weight were used.

The results of dry skin gunfire tests with the caliber .50 AP ordnance were as follows:

CALIBER AND TYPE	POWDER CHARGE %	MODE OF ENTRY	NO. OF ROUNDS	VELOCITY MAX. FT/S	MIN. FT/S	AVG. FT/S
.50 AP	100	Straight	5	2941	2878	2913
.50 AP	85	Straight	4	2395	2299	2357
.50 AP	50	Straight	5	1471	1399	1439
.50 AP	100	Tumbled	3	2878	2837	2857
.50 AP	85	Tumbled	4	2381	2260	2320
.50 AP	50	Tumbled	6	1418	1351	1398

The exceptionally small variance of the velocities includes the error inherent in the measuring device used, so a high degree of repeatability in projectile velocity was achieved.

The petal heights for caliber .50 AP straight-through rounds followed the same trend as the caliber .30, i.e., increasing petal height from thinnest to thickest material and petal height not affected by the panel alloy. The general trend of the increasing petal height, however, was not true of the caliber .50 tumbled rounds. The titanium alloy had the highest overall petaling for the caliber .50 AP rounds; the same was true for the caliber .30 AP rounds. The tumbled rounds had higher petals on the average than the straight-through shots by approximately 40 percent for any one powder charge. The aluminum panels exhibited no trend for one to have higher petals than another. Present in both calibers, but more prominent in the caliber .50, is the peak petal height reached in the center mounted skin for the tumbled rounds. For the tumbled caliber .50 rounds, the second skin panel (0.040 in. thick) had noticeably higher petals than the first (0.025 in. thick) and the third (0.080 in. thick). This could indicate that the largest amount of energy was absorbed by the second skin.

No correlation between alloy and petal height could be established. As with the caliber .30 tests, however, panel thickness did have some effect on the type of damage inflicted by the projectile. One alloy, the 7075-T6, suffered coring for every round fired through it. This was not true of any of the other alloys where coring occurred only in scattered instances. There was less coring with the caliber .50 than with the caliber .30. No cause was found for this phenomenon. About 40 percent of the holes made by caliber .50 rounds were undersize and about 60 percent of the holes made by the caliber .30 were undersize, even though the material setups were identical.

Figures F-1 through F-8 of Appendix F show photographs of all skins tested and Tables G-I through G-VIII of Appendix G show the measured detail size and comments on type of damage incurred by the panels. Round numbers T1 through T59, shown in the photographs, correspond to the round numbers listed in the tables of Appendix G. The effect of any one particular round can be traced through all three panels by the round number shown in the photograph and the correlating tabulated measurements and comments. For added convenience, the tables are cross-referenced to the photographic figure of the gunfired panel. Most of the photographs are views of the entrance and exit sides of the test panel. Some edge shots are included to show petal height and petal roll.

The measured height of any petal was the perpendicular distance from the aft side of the skin surface. The height measurement is not to be construed as a suitable skin gap clearance because many petals were rolled as much as 180 degrees. In the process of rolling, the petal height probably exceeded the final measured height. Good examples of rolled petals are shown in Figures F-2(b) and (d).

Round T10 shown in Figures F-2(a), (b) and (c), and T18 shown in Figures F-3(c) and (e) are good examples of shrapnel pitting, shown as bright spots around the hole in the second and third skins. This shrapnel pitting, which was coring from front skin, was much more pronounced with the tumbled rounds than with the straight-through rounds.

Rounds T17 and T18, shown in Figures F-3(a), (c) and (e), are examples of coring. Normally, shrapnel damage and burning of second and third skins will occur when all three skins are cored. Round T18 in Figure F-3(c) and (e) shows coring and shrapnel damage very clearly, but on the same figures, Round T17, which also cored, shows very few shrapnel marks. The burning that sometimes accompanies coring and shrapnel damage is not well defined in the photographs; however, its presence can be detected by the panel discoloration (darker) in the area of the projectile hole suxh as that shown by T26 in Figure F-4(c) and very well in Figure F-4(e). Some fireflashes and fireballs were observed during caliber .50 AP gunfiring with some being recorded on film. These were observed more on the 7075-T6 and AMS 4901 titanium panels than on the other alloys. During the caliber .30 firing, the flashes and fireballs were noticed only when the titanium skins were shot. These fire flashes appeared to accompany the tumbled rounds more than the straight-through shots. In some instances, the second and third skins showed unmistakable evidence of the presence of fireballs in that the front surface showed discoloration from heat and shrapnel damage from the first and second skins in the stack. There are additional descriptive notes listed at the bottom of the tables of Appendix G which further describe the damage to the skin panels.

SECTION VI

WET TANK GUNFIRE TESTS

1. TEST OBJECTIVES

The wet tank gunfire tests were to evaluate the performance of self-sealing materials and backing boards which were chosen for this part of the study. The self-sealing materials and backing boards were tested as combinations in conjunction with the following parameters:

Internal pressure: 0 to 2 psi

Skin Gaps: 0 to 1.25 inch

With and without reticulated foam or whiffle balls

Ordnance: Calibers .30 and .50 AP and API

Entry Mode: straight through and tumbled

Nine self-sealing materials, twelve backing boards, three defense composites, and two special materials were tested in this gunfire sequence.

2. TECHNICAL APPROACH

a. Gunfire Schedule

To accomplish the objectives of this program, a wet tank gunfire test program, outlined in the gunfire schedule, Table I, was developed. The combinations of materials described in the gunfire schedule were selected on the basis of past performance, vendor's recommended protection level, and past experience in the use of the materials. Those combinations which held the greatest promise of success were the ones scheduled for gunfire. All materials were tested for entrance and exit sealing under as nearly identical conditions as possible. Test parameters were closely controlled to obtain repeatable and comparable results. The parameters were chosen to be similar to those existing in a self-sealing fuel tank mounted in an airplane. The parameters varied are listed in the left hand column of the gunfire schedule, Table I.

Each of the material combinations was subjected to gunfire of the caliber for which the material was designed and qualified. The tests and performance evaluation were similar to procedures outlined in military specification MIL-T-5578. Additional tests were performed on some materials beyond the design performance level of the materials. The effect of incendiary projectiles was also examined. The projectile type and mode is also shown in Table I.

TABLE I

WET TANK GUNFIRE SCHEDULE

	BACKING BOARD		GILLFAB 1068 .025 THK.	GILLFAB 1068 .025 THK	GILLFAB 1075 .025 THK	GILLFAB 1075 .025 THK	AIR LOG. 700 SI- EN2-23	AIR LOG. 700 SI- EN2-23	AIR LOG. 114509- EN2-23	3M CO. HC-1101	AIR LOG. 114509- 102	GILLFAB 1068 .025 THK	GOODYEAR ARM018	GOODYEAR ARM1800	GILLFAB 1075 .030 THK
	SELF-SEALING MATERIAL		UNIROYAL U.S.179	FIRESTONE 1316-3	GOODYEAR FTL-13	UNIROYAL U.S.180	UNIROYAL U.S.180	GOODYEAR FTL11-3	DEFENSE Composite	DEFENSE Composite	DEFENSE Composite	GOODYEAR FTL-13	GOODYEAR FTL11-3	GOODYEAR FTL11-3	UNIROYAL U.S.173
	SKIN	MODE													
.30 Cal.	7075-T6 BARE ALUM .080THK.1.25IN.GAP	ST.IN	B_1												
.30 Cal.	2024-T3 CLAD ALUM. .080THK.,1.00 IN. GAP	ST.IN		B_3											
.30 Cal.	2024-T3 CLAD ALUM .040 THK., 1.00 IN.GAP	ST.IN			B_5										
.30 Cal.	2024-Te CLAD ALUM. .080 THK.,.75 IN. GAP	ST.IN				B_6									
.50 Cal.	7075-T6 BARE ALUM. .040THK.,1.25 IN. GAP	ST.IN					B_{18}								
.50 Cal.	6061-T6 BARE ALUM .040 THK., 1.25IN.GAP	ST.IN					B_{20}								
.30 Cal.	7075-T6 BARE ALUM. .040THK., ZERO GAP	ST.IN TUM.						B_8							
.50 Cal.	7075-T6 BARE ALUM. .040 THK.,1.25 IN.GAP	ST.IN						$B_{8.1}$							
.30 Cal.	7075-T6 BARE ALUM .080 THK.,.50 IN.GAP	ST.IN TUM.						B_{10}							
.30 Cal.	NO SKIN	ST.IN TUM.							B_9						
.30 Cal.	NO SKIN	ST.IN								B_{12}					
.30 Cal.	NO SKIN	ST.IN TUM.									B_{13}				
.30 Cal.	7075-T6 BARE ALUM. .040 THK.1.00 INGAP	ST.IN										B_{25}			
.50 Cal.	2024-T3 CLAD ALUM .989 THK., .50 IN.GAP	ST.IN TUM.											B_{26}		
.50 Cal.	6061-T6 BARE ALUM. .040THK., ZERO GAP	ST.IN TUM.												B_{27}	
.50 Cal.	6061-T6 BARE ALUM. .040 THK., .50IN. GAP	ST.IN													B_{28}

TABLE I (CONTINUED)

	BACKING BOARD		AIR LOG. 700SI-EN2-41	FIRESTONE F1-41	GOODYEAR ARM018	GILLFAB 1068 .030 THK	CONOLITE B33FGIW	GOODYEAR ARM1800	AIR LOG. 700SI-EN2-41	FIRESTONE B-2	CONOLITE B33FGIW	AIR LOG. 700SI-EN2-41	AIR LOG. 700SI-EN2-23	AIR LOG. 700SI-EN2-41 Ex.	GOODYEAR FLC-1
	SELF-SEALING MATERIAL		UNIROYAL U.S.182	UNIROYAL U.S.182	UNIROYAL U.S.173	UNIROYAL U.S.182	GOODYEAR DX325	UNIROYAL U.S.182	GOODYEAR DX325	FIRESTONE F-1146	UNIROYAL U.S.179	FIRESTONE 1316-3	GOODYEAR FTL-13	114509-304 Ent. DX325 Exit	
	SKIN	MODE													
.50 Cal.	6061-T6 BARE ALUM .080 THK., .50IN.GAP	ST.IN	B_{29}												
.50 Cal.	6061-T6 BARE ALUM .080 THK., ZERO GAP	ST.IN TUM.	B_{30}												
.50 Cal.	2024-T3 CLAD ALUM .040 THK., .50 IN. GAP	ST.IN		B_{31}											
.50 Cal.	6061-T6 BARE ALUM .040 THK., .25 IN. GAP	ST.IN		B_{32}											
.50 Cal.	2024-T3 CLAD ALUM .080 THK., .25 IN. GAP	ST.IN TUM.			B_{34}										
.50 Cal.	6061-T6 BARE ALUM .080 THK.,1.25 IN. GAP	ST.IN				B_{37}									
.50 Cal.	2024-T3 CLAD ALUM .040 THK.,1.25 IN. GAP	ST.IN					B_{39}								
.50 Cal.	2024-T3 CLAD ALUM .040 THK., ZERO GAP	ST.IN						B40							
.50 Cal.	2024-T3 CLAD ALUM .080 THK., ZERO GAP	ST.IN TUM.							B43						
.50 Cal.	7075-T6 BARE ALUM .080 THK., .25 IN. GAP	ST.IN								B_{49},$B_{49.1}$					
.30 Cal.	2024-T3 CLAD ALUM .040 THK., .25 IN. GAP	ST.IN TUM.									B51				
.30 Cal.	2024-T3 CLAD ALUM .040 THK., .25 IN. GAP	ST.IN									$B_{51.1}$				
.30 Cal.	7075-T6 BARE ALUM .040 THK., .25 IN. GAP	ST.IN TUM.										B52			
.30 API	(SKIN ON FRONT SIDE ONLY)	ST.IN										B52.1			
.30 Cal.	(SKIN ON FRONT SIDE ONLY)	ST.IN										B52.2			
.50 API	7075-T6 BARE ALUM .040 THK., .25 IN. GAP	ST.IN										$B_{52.3}$			
.30 Cal.	6061-T6 BARE ALUM .080 THK., .25 IN. GAP	ST.IN											B_{53},$B_{53.1}$		
.30 Cal.	2024-T3 CLAD ALUM .080 THK.,1.25 IN. GAP	ST.IN TUM.												B48	
.50 Cal.	2024-T3 CLAD ALUM .080 THK.,1.25 IN. GAP	ST.IN TUM.												B48.1	
.30 Cal.	NO SKIN	ST.IN													B21
.50 Cal.	NO SKIN	ST.IN													B22

The following discussion provides a brief explanation of the organization and logic of the gunfire test schedule, presented in Table I.

(1) The smallest sub-division, noted by the symbol ■, is a setup. Each setup represents a complete test fixture assembly to be subjected to as many as three identical rounds. When either the projectile entry mode, caliber, or type is changed, it is considered to be a different setup, even though the test fixture has not been reworked. Internal pressure was the only parameter varied during the shooting of any given setup.

(2) A block, identified by brackets and the notation, Bn, consists of one or more setups. Each block could be subjected to a number of different calibers, types, or modes of entry of projectile without reworking the test fixture. Those blocks numbered Bn.1 are configurations that had passed initial tests and were scheduled to receive an increased caliber or an armor piercing incendiary round for further evaluation.

b. Test Materials

The materials chosen for testing to fulfill the various objectives of the program ranged from totally experimental to fully qualified. The materials are believed to be representative of the spectrum of materials available today. The balance of the materials listed in Tables E-II and E-III of Appendix E were omitted from the test program, either because some degree of duplication would have been experienced, as with the light weight Conolite, or because the material was unavailable from the manufacturer, as with Goodyear ARM-024.

(1) Backing Boards

The following backing board compositions were selected for testing:

- o Conolite B33FG1W
- o Goodyear Aerospace ARM-018
- o Goodyear Aerospace ARM-1800
- o M. C. Gill Gillfab 1068 (0.025 and 0.030)
- o M. C. Gill Gillfab 1075 (0.025 and 0.030)
- o Air Logistics 700 SI-EN2-23
- o Air Logistics 700 SI-EN2-41
- o Air Logistics 700 SI-EU1-61
- o Firestone F1-41
- o Firestone B-2

(2) Self-Sealing Tank Materials

The basic self-sealing constructions were selected for testing as follows:

- o UniRoyal US 173
- o UniRoyal US 179
- o UniRoyal US 180
- o UniRoyal US 182
- o Goodyear FTL 11-3
- o Goodyear FTL-13
- o Goodyear DX325
- o Firestone 1146
- o Firestone 1316-3

(3) Protective Materials for Metal and/or Integral Tanks

Five special protective materials were selected for testing:

- o 3M Company HC-1101
- o Goodyear FLC-1
- o Air Logistics 114509-102
- o Air Logistics 114509-217
- o Air Logistics 114509-304

(4) Special Materials

The following special materials were selected to be included in the test program for limited evaluation only:

- o Firestone LAS-103ZF Orange Foam
- o Kent Mfg. BTG-6

c. Test Methods

(1) Test Fixture

A test fixture was designed and fabricated as shown in Figure 3. This box disassembles into two end frames, in which a skin assembly may be mounted, and a center section tank. A piece of 28 by 34 inch self-sealing material and backing board was clamped to each end of the center section tank between the tank face and end frame face. This connection is liquid- and air-tight when clamped. The purpose of clamping the end frames to the tank was to allow for a quick method of changing test materials. The area available for projectile entry and exit without striking the end frame structure is contained in three bays, each approximately 8 inches by 24 inches. Various skin assemblies were installed in the end frame assemblies to create a skin to

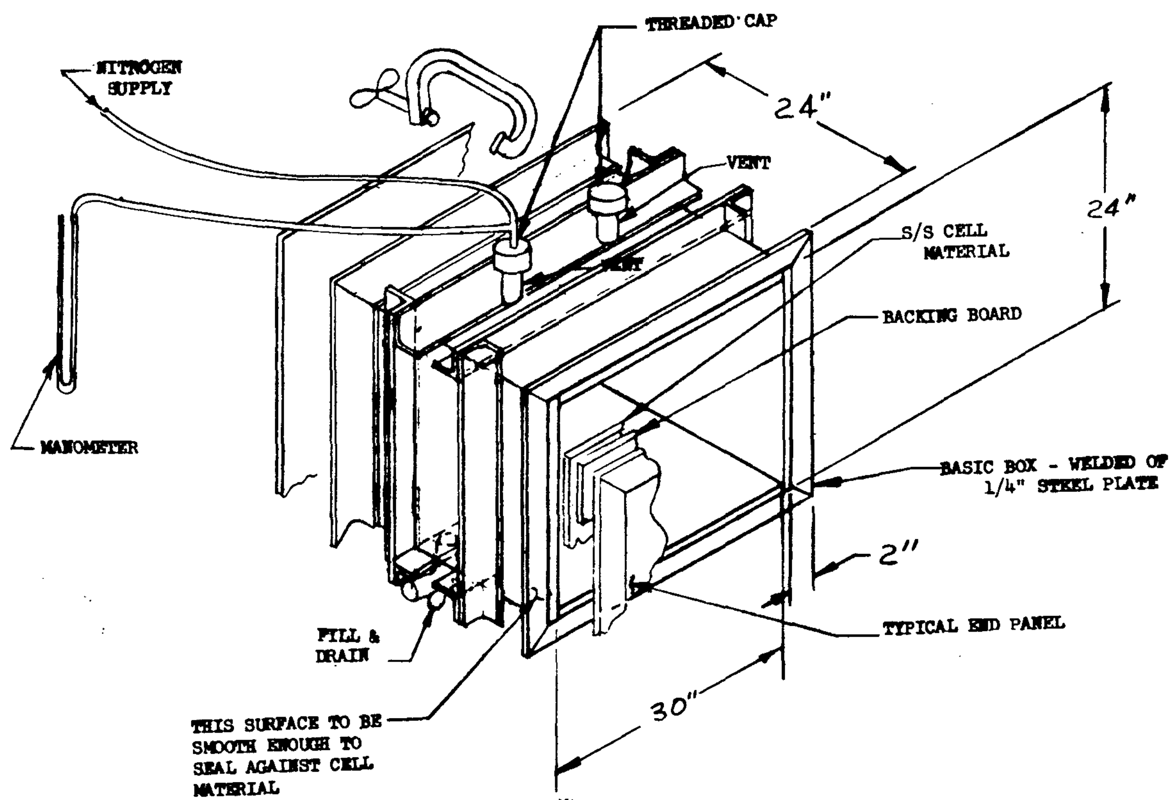


FIGURE 3
BASIC TEST BOX
(Supports and Spillage Pan not shown)

backing board gap varying from zero to 1.50 inches. This arrangement provided a test tank 24 inches deep through which a projectile could pass for entry and exit study. The complete test fixture was placed on a table as shown in Figure 4. The locations of the guns, fuel storage tanks, fuel pumps, nitrogen supply for regulating internal tank pressure, tumble boards, and velocity measuring equipment are also shown in Figure 4.

(2) Tumble Boards

In order to achieve tumbled projectile impacts, tumble boards were used. Various tumble board thicknesses, materials, and locations were examined to achieve a repeatable result. The configuration shown in Figure 5 was adopted as the most suitable for this purpose.

(3) Gunfire Sequence

A typical gunfire sequence for any test material combination consisted of the following:

ROUND	MODE	PRESSURE	FIXTURE BAY	
1	Straight	0	L. H.	
2	Straight	2	Center	
3	Straight	1	R. H.	Note 1
4	Tumbled	0	L. H.	
5	Tumbled	2	Center	
6	Tumbled	1	R. H.	
7	Straight	0	Any	

NOTE 1: If combination withstood the damage of rounds 1 and 2, number 3 was not fired. If the combination sealed satisfactorily for straight-through rounds, rounds 4 and 5 were fired. If the combination survived 4 and 5, round 6 was not fired. If both straight-through and tumbled rounds were successfully completed, an incendiary round was fired into the specimen after installing reticulated foam in the tank as a fire suppressant.

It should be noted that the Blocks were not fired in numerical sequence. The sequence of testing was established by the availability of the test materials, previous test results, and the convenience to the test engineer. The order of testing can be derived from the round number identification, i.e., the rounds are listed in numerical order from T1 through T85 as they were fired.

In addition to normal tests, some material combinations were tested with projectiles above and/or below the protection level recommended by the manufacturer. Examples are B2, B8, B10 and B52. These additional

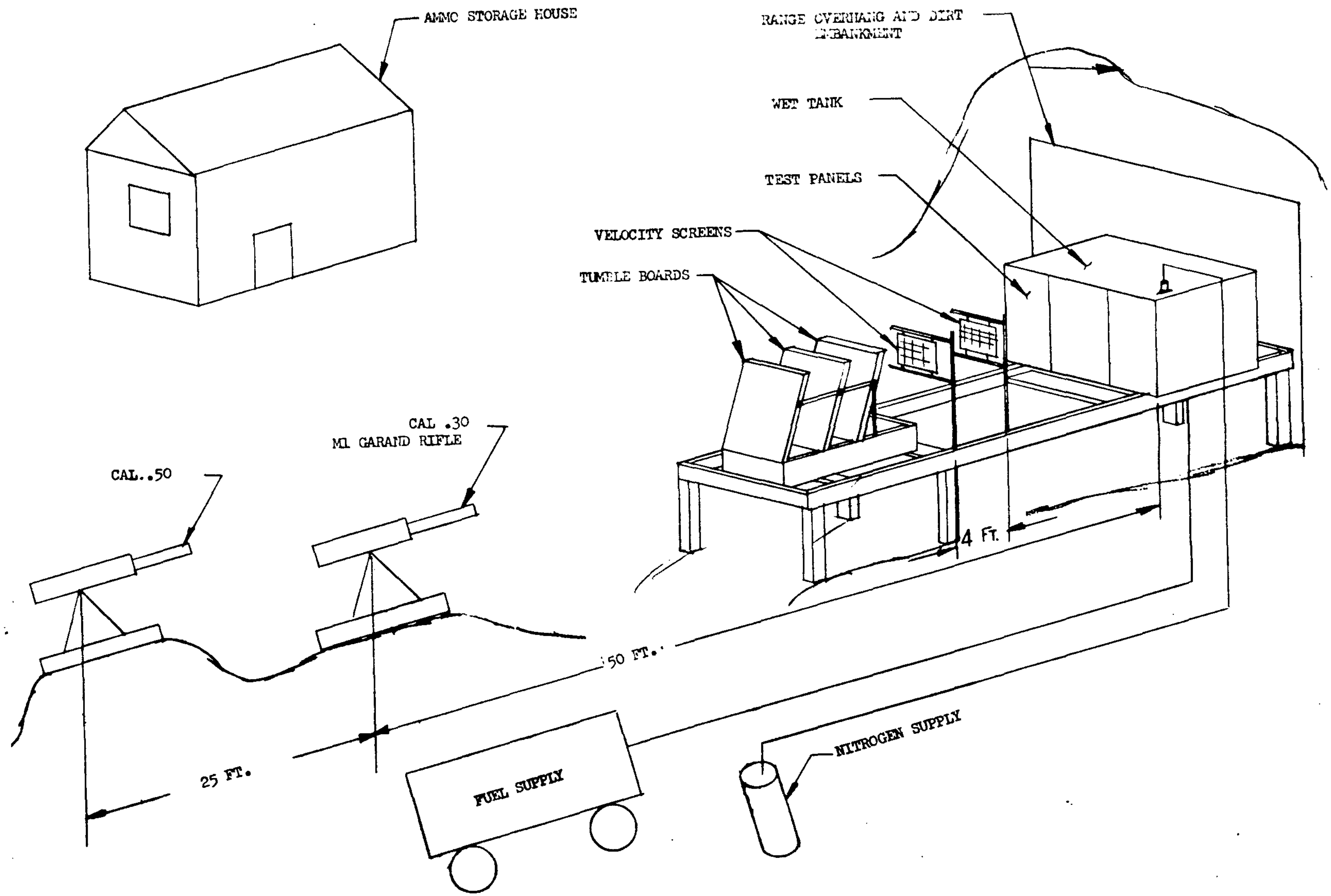
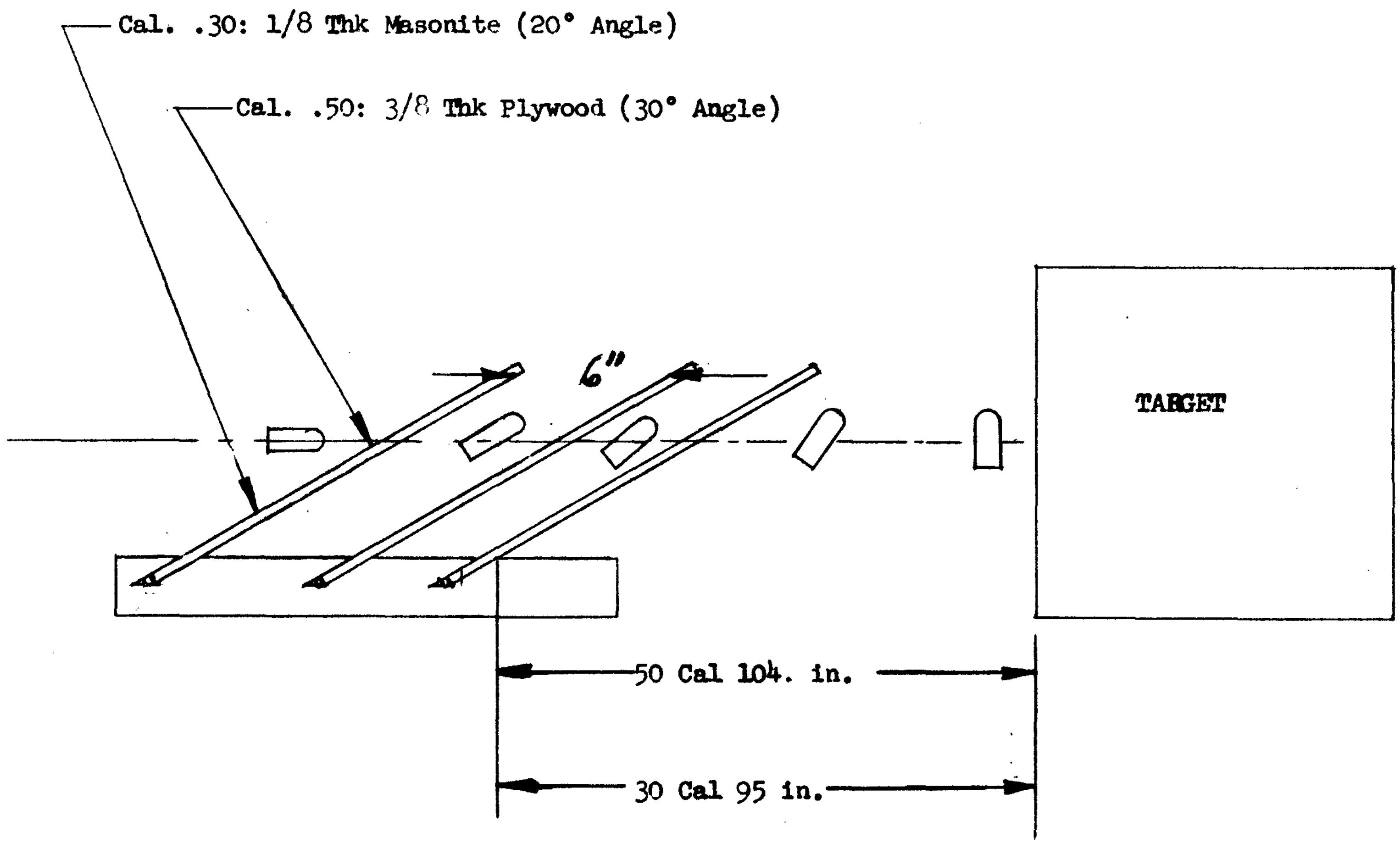


FIGURE 4
SCHEMATIC OF GUNFIRE RANGE

FIGURE 5

Side View of Tumbled Rounds



tests were performed to see if any combinations would perform satisfactorily above and beyond the level for which it was manufactured. Figure 6 shows the gunfire sequence for each round and the possible paths which any one block could follow. Figure 7 is a modified gunfire sequence which was adopted in the latter part of the program to reduce the time required to complete the test program. Blocks B49, B51, and B53 were fired in the sequence set up in Figure 7.

Three special materials and/or "defense composites" were also tested to determine sealing capabilities against both caliber .30 and .50 projectiles. Examples are B9, B11, B12, B13, B14, B21, B22, B23, B24, B46, B47, and B48 shown on the gunfire schedule, Table I.

3. GENERAL RESULTS

The major purpose of the wet tank gunfire program was to evaluate the self-sealing backing board combinations defined in Table I. Most of the combinations failed before a complete sequence of seven or more rounds was fired into them. This fact, however, did not detract from the significance of these test results.

Early in the gunfire test program, results indicated that the material combinations were being subjected to more stringent test conditions than were anticipated or desired in that excessive hydraulic ram pressure was being experienced in the test fixture when the specimens were gunfired. Because of the existence of this high pressure, the exit data collected is not so complete as that collected on the entrance side. From one point of view, this condition of high ram pressure is over penalizing to the exit since the total pressure is applied to the exit side material and backing board in both a ram pressure and rarefaction wave. There was marked evidence of this return wave force in that some exit-side materials and backing board were pulled forward from the aft face into the fuel area of the test fixture. In addition to the forces of the rarefaction wave, there was also the forward force from the dynamic impact of the aft panel returning to its original position following the deformation induced by the initial ram pressure wave. It is believed that the stiffness of the tank walls prevented any dissipation of excess hydraulic pressure through the tank and caused the full force to be imposed on the exit panels. This setup is unrealistic only to the extent that ram pressure cannot dissipate in all directions and be absorbed by a "working structure" such as is present in most aircraft fuel tank cavities. The presence of this ram pressure was noticed early and observed closely throughout the wet tank gunfire program. Because measurement of these pressures is extremely difficult, no measurements were attempted as part of this program, although the effects of it were easily observed.

The design of such a rigid test fixture was dictated by several criteria. First, the fixture would be subjected to numerous high impact forces. Second, only test panels for end mounting, not cubes, were to be tested. Third, in addition to economic feasibility, the fixture must be resistant to fire and explosion. The clamping of the end frames assemblies to the tank body was incorporated to provide a faster and more efficient means to change test configurations. Early attempts to use toggle-type clamps proved unsatisfactory. For the remainder of the test program, higher strength clamps were used.

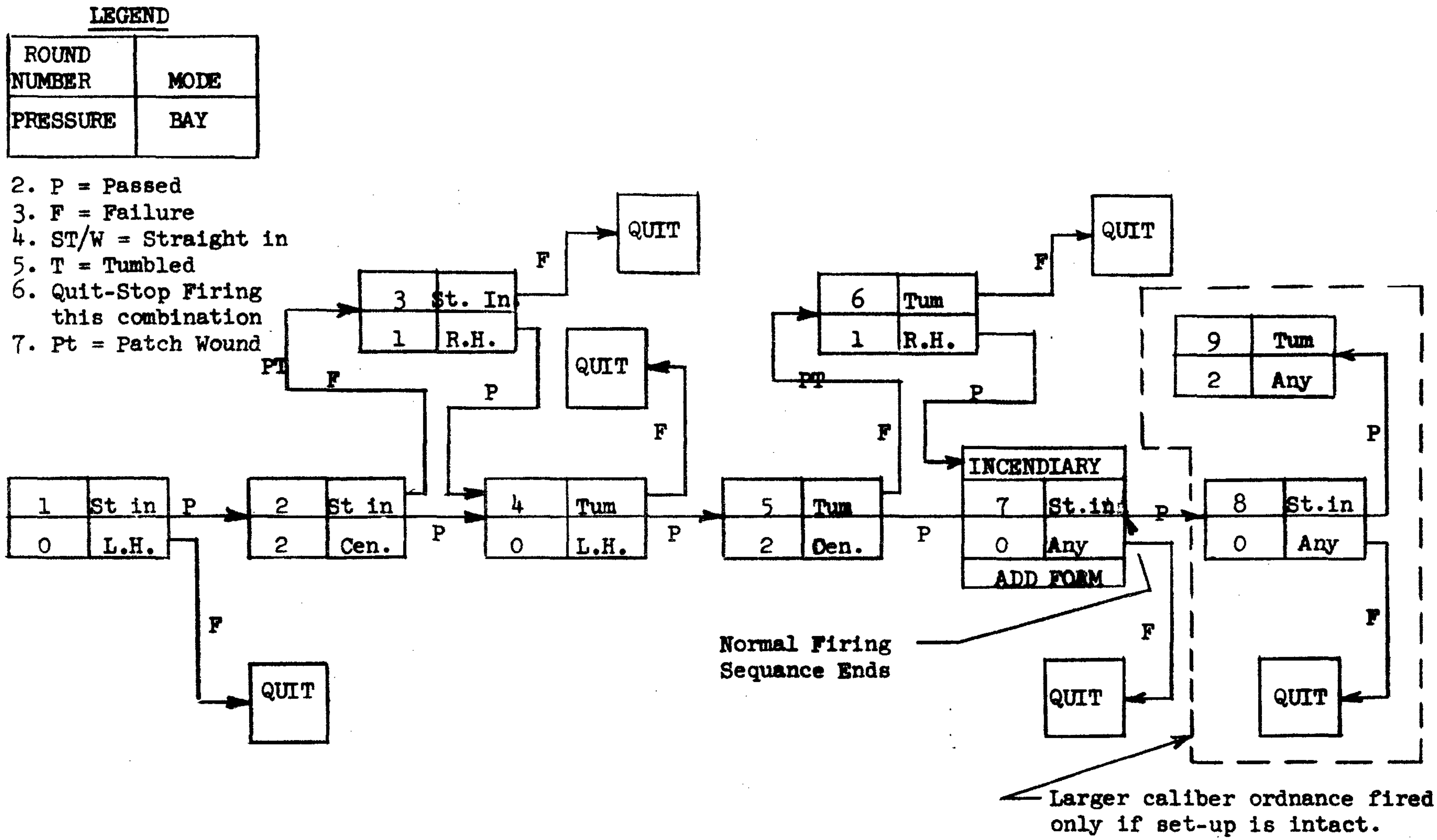


FIGURE 6. GUNFIRE SEQUENCE

LEGEND

P	=	Passed
F	=	Failed
T	=	Tumbled
ST IN	=	Straight in
INC	=	Incendiary Round Block
PT	=	Patch Wound
QUIT	=	Quit Firing This Combination
FOAM	=	Add Foam or Whiffle Balls

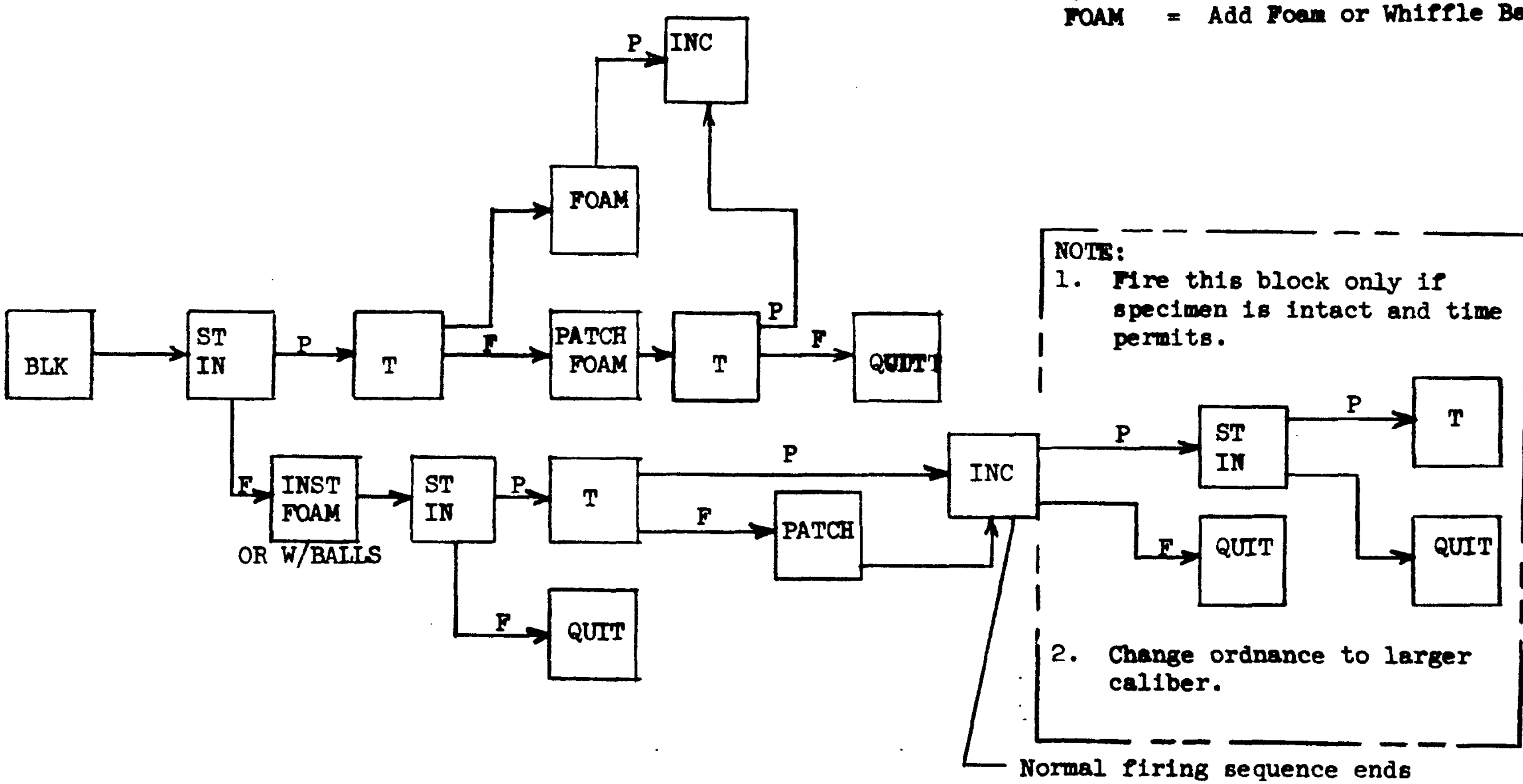


FIGURE 7. GUNFIRE SEQUENCE

A summation of the seals obtained during the wet tank gunfire tests is given in Tables II, III, and IV. Table II shows the very good entrance seals achieved with the straight-in rounds. It should also be noted that these results were gained with variations of pressure from 0 to 2 psig, and skin gap of 0 to 1.50 inches. In all cases, the caliber ordnance used on any combination was that which the material vendor recommended. It appeared that the internal pressure applied had no noticeable effect on the sealing capabilities of the material for the straight-in entrance rounds. Neither is there any evidence to say that the skin gap had any effect on the sealing efficiency. Judgment as to where a seal was obtained was based on the criteria of MIL-T-5578, so for the remarks section of Table II, only a time element was added.

Table III is a summation of the tumbled entrance rounds. The same variables of pressure and skin gap exist here as in Table II; however, the results were not so clearly defined. Without exception, all rounds were in a tumbled mode at the exit panel. Of the eight sealing failures suffered, four were from simultaneous coring of the backing board and tank material; one from skin metal lodged in the wound; one from 2 psig pressure; one tank material cored and split; and one caught fire upon impact. If the 23 tumbled rounds listed here could be considered typical, approximately two-thirds of the time a seal will be achieved from shrapnel hits.

Table IV is a compilation of the exit seals obtained during the wet tank tests. Of the 85 rounds fired, 35 of these would have to be considered sealing failures on exit. Seven failures of the "defense composites" were not counted. Bearing in mind that a high ram pressure was present, a close examination of each failure was made to determine the cause of failure. The sealing results "remarks" column of Table IV reveals the following facts: 15 backing board support failures; 9 self-sealing material coring failures; 3 combination material and backing board failures; 3 "no sealant" activation failures; 2 due to failures of test fixture; 4 miscellaneous failures due to not sealing in four minutes and other causes. The 15 backing board failures should not be considered as condemnation of "State of the Art" for boards now supplied by industry. Ten of these failures were fired with Gillfab 1068 and 1075 backing boards which failed every time, no matter what self-sealing material was combined with it. Half of these failures were under internal pressure when the failures occurred, so there is a decided pressure influence no matter what other cause of failure may be present. Of the total rounds fired, 20 were fired into setups with zero skin gap. Only five failures occurred in this group of 20 with four of them attributable to material coring; thus it can be deduced that the skin absorbed some of the hydraulic ram pressure to decrease the percentage of failures. The effect of the internal pressure appeared to have noticeable effect on exit but none on entrance wound sealing. At entrance, the internal pressure seems to be offset by the reverse or rarefaction impact pressure wave to aid in repositioning the tank wall against the forward backing board.

Of those material combinations gunfired, not all will be discussed in detail because some setups did not yield the information sought and some duplication of results occurred. However, the results of all gunfired combinations were used in the analysis of the data collected. Selected test results are discussed in the following section.

TABLE II

COMPARISON OF ENTRANCE SEALS

STRAIGHT IN SHOTS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS SEAL	REMARKS
B12	T1	.30AP	0	No Skin	YES	Immediate
B21	T2	"	0	"	"	"
	T3	"	1	"	"	"
	T4	.30AP	2	"	"	"
B22	T5	.50AP	0	No Skin	"	"
B8	T6	.30AP	0	0	"	"
	T7	.30AP	1	0	"	"
B8.1	T10	.50AP	0	0	"	"
B18	T11	.50AP	0	1.25	"	"
	T12	.50AP	0	1.25	"	"
B10	T13	.30AP	0	.50	"	"
	T14	"	2	.50	"	"
	T15	"	1	.50	"	"
B9	T19	"	0	No Skin	"	"
	T20	"	2	No Skin	"	"
	T21	"	1	No Skin	"	"
B1	T23	"	0	1.25	"	"
	T24	"	2	1.25	"	"
B5	T25	"	0	1.00	"	"
B3	T26	"	0	1.00	"	"
B6	T27	"	0	.75	"	Seeped for 2 min, then sealed
	T28	"	2	.75	"	Immediate
B20	T29	.50AP	0	1.00	"	"
B25	T31	.30AP	0	1.00	"	"

TABLE II (Continued)

COMPARISON OF ENTRANCE SEALS

STRAIGHT IN SHOTS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS	
					SEAL	REMARKS
B48	T32	.30AP	0	1.25	YES	Immediate
	T33	.30AP	0	1.25	"	"
B48.1	T35	.50AP	0	1.25	"	"
B29	T37	.50AP	0	1.40	"	"
B27	T38	.50AP	0	0	"	"
	T39	.50AP	2	0	"	"
	T40	.50AP	1	0	"	"
B13	T43	.30AP	0	No Skin	"	"
	T44	"	2	No Skin	"	"
	T45	"	1	No Skin	"	"
B26	T48	.50AP	0	1.50	"	"
	T49	"	2	1.50	"	"
B34	T52	"	0	.25	"	"
	T53	"	2	.25	"	Sealed in 1 min.
	T54	"	1	.25	"	Immediate
B28	T56	"	0	1.50	"	"
	T57	"	2	1.50	"	"
B30	T58	"	0	0	"	"
	T59	"	2	0	"	"
	T60	"	1	0	"	Sealed in 1 min.
B32	T62	"	0	.25	"	Immediate
B31	T63	"	0	.50	"	"
	T64	"	2	.50	"	"
B37	T65	"	0	1.25	"	"

TABLE II (Continued)

COMPARISON OF ENTRANCE SEALS

STRAIGHT IN SHOTS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS	
					SEAL	REMARKS
B39	T66	.50AP	0	1.25	YES	Immediate
B40	T67	"	0	0	"	"
B43	T68	"	0	0	"	"
	T69	"	0	0	"	"
	T70	"	2	0	NO	Sealed when pressure dropped to 0 PSIG
B51	T73	.30AP	2	.25	YES	Immediate
B51.1	T75	"	2	.25	"	"
B53	T76	"	2	.75	"	"
B49	T77	.50AP	2	.25	"	"
B53.1	T78	.30AP	2	.75	"	"
B49.1	T79	.50AP	2	.25	"	"
B52	T80	.30AP	2	.25	"	"
B52.1	T83	.30API	2	.25	"	With slight seep. Not measurable.
B52.2	T84	.50AP	2	.25	"	Immediate

TABLE III

COMPARISON OF ENTRANCE SEALS

TUMBLED SHOTS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS	
					SEAL	REMARKS
B8	T8	.30AP	0	0	YES	Damp Seal in 1 minute
	T9	.30AP	1	0	YES	Immediate
B10	T16	.30AP	0	.50	YES	Immediate
	T17	"	2	.50	NO	Dripped for 4 minutes
						Dried in 10 minutes
	T18	"	1	.50	YES	Immediate
B9	T22	"	0	No Skin	"	"
B20	T30	.50AP	0	1.00	NO	Caught fire on impact
B48	T34	.30AP	0	1.25	YES	Immediately
B48.1	T36	.50AP	0	1.25	NO	Cored Tank material and
						backing board
B27	T41	.50AP	0	0	YES	Immediately
	T42	.50AP	2	0	YES	Damp seal in 2 min.
B13	T46	.30AP	0	No Skin	YES	Dry in 3 minutes
	T47	.30AP	2	No Skin		Hit above fuel
B26	T50	.50AP	0	1.50	YES	Immediately
	T51	.50AP	2	1.50	YES	Damp seal in 2.5 minutes
B34	T55	.50AP	0	.25	NO	Cored
B30	T61	.50AP	0	0	NO	Flowed .25 gal/min.
B43	T71	.50AP	0	0	NO	Constant Trickle
	T72	.50AP	2	0	NO	" "
B51	T74	.30AP	2	.25	YES	Only after pressure dropped
						to 0 psig
B52	T81	.30AP	2	.25	YES	Immediate

TABLE III (Continued)

COMPARISON OF ENTRANCE SEALS

TUMBLED SHOTS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS SEAL	REMARKS
B52	T82	.30AP	2	.25	YES	Damp seal immediately. Dry in 3 min.
B52.3	T85	.50API	2	.25	NO	Cored

TABLE IV

COMPARISON OF EXIT SEALS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS	
					SEAL	REMARKS
12	T1	.30AP	0	NoSkin	NO	Ram pressure wave
21	T2	"	0	No Skin	N.A.	No projectile exit
	T3	"	1	"	N.A.	No projectile exit
	T4	"	2	"	N.A.	No projectile exit
22	T5	.50AP	0	"	NO	Material cored and split
8	T6	.30AP	0	0	YES	Immediate
	T7	.30AP	1	0	YES	Immediate
	T8	"	0	0	N.A.	No projectile exit
	T9	"	1	0	N.A.	No projectile exit
8.1	T10	.50AP	0	0	NO	Cored - No backing
18	T11	.50AP	0	1.25	NO	Cored
	T12	"	0	1.25	NO	Cored & Split Material
10	T13	.30AP	0	.50	YES	Immediate
	T14	"	2	.50	NO	Sealed in 9 minutes
	T15	"	1	.50	YES	Immediate
	T16	"	0	.50	N.A.	No projectile exit
	T17	"	2	.50	YES	
	T18	"	1	.50	YES	
9	T19	"	0	No Skin	NO	
	T20	"	2	" "	NO	
	T21	"	1	" "	NO	
	T22	"	0	No Skin	N.A.	No projectile exit
1	T23	"	0	1.25	NO	Backing Board Failed
	T24	"	2	1.25	NO	Backing Board Failed

TABLE IV (Continued)

COMPARISON OF EXIT SEALS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS	
					SEAL	REMARKS
5	T25	.30AP	0	1.00	NO	Backing board failed
3	T26	"	0	1.00	NO	No sealant activation
6	T27	"	0	.75	YES	Dry in 2 minutes
	T28	"	2	.75	NO	No sealant activation
20	T29	.50AP	0	1.00	NO	Backing board failed
	T30	.50AP	0	1.00	NO	Caught Fire
25	T31	.30AP	0	1.00	NO	Material and backing board split
48	T32	.30AP	0	1.25	NO	Projectile held wound open
	T33	"	0	1.25	N.A.	No projectile exit
	T34	"	0	1.25	N.A.	No projectile exit
48.1	T35	.50AP	0	1.25	YES	Damp in 3 minutes
	T36	"	0	1.25	YES	Immediate
29	T37	"	0	1.40	NO	Backing board failed
27	T38	"	0	0	YES	Immediate
	T39	.50 AP	2	0	YES	Immediate
	T40	"	1	0	YES	Damp immediately
	T41	"	0	0	YES	Dry in 1 minute
	T42	"	2	0	YES	Dry in 3 minutes
13	T43	.30AP	0	No Skin	NO	Constant 150 drops 1 minute
	T44	.30AP	2	No Skin	NO	Constant drip at 0 psig
	T45	"	1	" "	NO	Constant seep
	T46	"	0	" "	YES	Damp in 3 minutes
	T47	"	2	No Skin	NO	Material cored
26	T48	.50AP	0	1.50	NO	Wound misaligned

TABLE IV (Continued)

COMPARISON OF EXIT SEALS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS	
					SEAL	REMARKS
26	T49	.50AP	2	1.50	YES	Dry in 1 minute
	T50	.50AP	0	1.50	YES	Dry in 3 minutes
	T51	.50AP	2	1.50	YES	Damp seal in 2.5 minutes
34	T52	.50AP	0	.25	NO	Structural Failure
	T53	.50AP	2	.25	NO	Wound misaligned
	T54	.50AP	1	.25	NO	Wound misaligned
	T55	.50AP	0	.25	YES	Immediate
28	T56	.50AP	0	1.50	NO	Backing board failed
	T57	.50AP	2	1.50	NO	Wound misaligned
30	T58	.50AP	0	0	NO	Tank material split
	T59	.50AP	2	0	YES	Damp seal in 2.5 minutes
	T60	.50AP	1	0	YES	Damp seal in 2.5 minutes
	T61	.50AP	0	0	YES	Immediate
32	T62	.50AP	0	.25	NO	Tank cored
31	T63	.50AP	0	.50	NO	Wound misaligned
	T64	.50AP	2	.50	NO	Backing board failed
37	T65	"	0	1.25	NO	Backing board failed
39	T66	"	0	1.25	NO	Backing board failed & tank split
40	T67	"	0	0	NO	3 gal/minute
43	T68	"	0	0	NO	Cored
	T69	"	0	0	YES	Damp immediately
	T70	.50AP	2	0	YES	When pressure dropped to 0 psig
	T71	"	0	0	YES	Immediate
	T72	"	2	0	NO	Wound misaligned

TABLE IV (Continued)

COMPARISON OF EXIT SEALS

BLOCK	ROUND	CALIBER	PRES (PSIG)	SKIN GAP (IN.)	SEALING RESULTS SEAL	REMARKS
51	T73	.30AP	2	.25	NO	Constant seepage
	T74	"	2	.25	N.A.	No projectile exit
51.1	T75	.30API	2	.25	N.A.	No projectile exit
53	T76	.30AP	2	.75	NO	Tank material split
49	T77	.50AP	2	.25	NO	No sealant activation
53.1	T78	.30AP	2	.75	NO	Tank material split
49.1	T79	.50AP	2	.25	NO	Tank and B/B failed
52	T80	.30AP	2	.25	YES	Dry seal in 2 minutes
	T81	.30AP	2	.25	N.A.	No projectile exit
	T82	"	2	.25	N.A.	No projectile exit
52.1	T83	.30API	2	.25	N.A.	No projectile exit
52.2	T84	.50AP	2	.25	YES	Damp seal in 1 minute
52.3	T85	.50API	2	.25	YES	

4. INDIVIDUAL TEST DISCUSSIONS

a. Series 1

This material combination was an unusual one in that a caliber .50 protection level, self-sealing material, FTL 11-3 from Goodyear Tire and Rubber Co. was matched with a caliber .30 protection level backing board, Air Logistics 700SI-EN2-23. This combination was fired with both caliber .30 and .50 armor piercing rounds to determine the importance of support to self-sealing materials. In addition, this same combination, Block B10, was selected to show the effects of partial fuselage skin petaling, where block B8 was set up for zero skin gap.

(1) Block B10

This configuration was intended to create partial petaling of the fuselage skin into the backing board and the self-sealing material wound. The skin was 0.080 inch thick 7075-T6 bare aluminum alloy with a backing board spacing of 0.50 inch. The skin gap proved to be too great and no petaling interference was achieved.

All six rounds, three straight-in and three tumbled, sealed satisfactorily as shown in Appendix J, Rounds T13 through T18. The second and third straight-in (T14 and T15) and fifth and sixth tumbled (T17 and T18) were fired under 2 and 1 psig pressures respectively. None of the tumbled rounds (T16, T17, T18) or straight-in (T14) exited through the aft panel, but did impinge on the aft panel of self-sealing material with no noticeable damage.

Block B10 verified acceptable performance of self-sealing material when penetrated by a lower caliber round than the qualified protection level, with or without internal pressure, with a correspondingly lighter backing board.

(2) Block B8, B8.1

This configuration created a severe petaling condition because of a zero clearance between the fuselage skin and the backing board. The effort to defeat sealing because of petaling failed this time also. The skin was 0.040 thick 7075-T6 bare alloy. Sealing at both entrance and exit wounds was satisfactory with caliber .30 AP rounds (T6, T7, T8, T9) in both straight-through and tumbled modes. Figure H-1 of Appendix H and rounds T6 through T10 of Appendix J exhibit the results of the firing.

After the specimen passed the first four rounds, it was decided to fire the configuration with a caliber .50 straight-through round. Block B8.1 was one caliber .50 round straight through, and Figures H-1(c), (d), (e) and (f) display the results. Sealing was achieved on entrance but the exit panel did not seal. Figure H-1(d) shows the catastrophic effect of a caliber .50 tumbled exit round. In this case the skin was completely destroyed, the backing board failed, and no sealing occurred. Figures H-1(e) and (f) picture the debris found inside the tank and the condition of the exit side backing board.

This sequence is an example of the necessity of a good backing board. When fired with caliber .30 ordnance, sealing was good for caliber .30 board and caliber .50 material; but when fired with caliber .50 ordnance, total loss of sealing capability resulted on exit.

b. Series 2

This configuration was made of Goodyear's FTL 11-3 self-sealing material and ARM 018 backing board, both caliber .50 protection level. A skin to backing board gap of 1.25 inches was established. The complete configuration was to be typical of an aircraft installation with one exception, that being that the backing board was allowed to float within the end frame. The purpose of this test was to determine if an unrestrained board which could deflect with the ram pressure waves would provide better support than a restrained board. Also, a check on the overall performance of this combination was sought.

This series contained only one block, B26. Figure H-2 and Rounds T48 through T51 of Appendix J adequately describe the results. Four caliber .50 rounds (T48, T49, T50, T51) were fired into this setup, two straight and two tumbled. The first round, T48, at zero head pressure, did not seal on exit. Figure H-2(d) shows a long tear in the backing board from a partial tumbled exit causing loss of support so that no seal was achieved. The other rounds fired with and without pressure and a change of mode sealed satisfactorily. The backing board damage of round T49 was not so extensive as T48 and permitted satisfactory sealing. Application of pressure after gunfire revealed no leakage. It was felt that this configuration performed very well. Figures H-2(a), (b), and (f) show skin damage, and Figure H-2(e) is a picture of the inside of tank looking in the direction of projectile paths. Based upon the results of this test and blocks B28 and B34, it is believed that the floating backing board contributed nothing worthwhile to the fuel tank installation.

c. Series 3

This series, which contained only one block, B27, was established as a sequel to B26 with one parameter change. The skin gap was reduced from 1.25 inches to zero inches. The self-sealing material was FTL 11-3 and the backing board was ARM 1800 both Goodyear products, but from separate company divisions. It was believed that by creating a petaling situation on materials that had already shown good sealing and support capabilities, an insight into the effects of petaling interference could be achieved.

Five caliber .50 AP rounds (T38, T39, T40, T41, T42) were fired in this block, three straight-in and two tumbled. All wounds sealed well in both entrance and exit sides in a head pressure range of zero to 2 psig. In addition to the good sealing and support performance displayed by this combination, the performance becomes more notable when reviewed in the photographs of Figure H-3. It can be observed that from the first to last round, support from the skin to the backing board was systematically destroyed, yet sealing continued. In comparing Figure H-3(b) to (a) and (f), the wounds in the backing board are small and unfrayed as compared to the complete destruction of the 0.040 inch thick 6061-T6 bare aluminum skin. Some shallow petaling occurred on the entrance skin but did not adversely affect the sealing. Figure H-3(e) is a photograph of the tank interior showing skin shrapnel which passed through the self-sealing material and backing board and stopped in the tank.

d. Series 4

This block, B34, was primarily a continuation of the test conditions initiated in Block B26 as far as the floating backing board. This board, Goodyear ARM 018, was matched with UniRoyal's U.S. 173 self-sealing material, a combination of proven materials. A skin gap of 0.25 inches was used with a 2024-T3 aluminum alloy skin panel. This test was the third attempt to achieve petaling interference.

Four caliber .50 rounds were fired, three straight-in and one tumbled. Satisfactory seals on entrance were achieved for three straight-in shorts only. None of the exit wounds inflicted in this series sealed. The results of this block and blocks B26 and B28 demonstrate that the backing board adds more to sealing action in the restrained installation than it does when it is floating.

Because of its unrestrained condition, the backing board offered no resistance to ram pressure created by round T52. Figures H-4(d), (e) and (f) show the exit side damage created by round T52 when the backing board is not present to help absorb some of the ram pressure load. Figures H-4(a), (b) and (c) show the entrance, backing board, and exit damage sustained by this block which had unrestrained backing board.

e. Series 5

This series was made up of caliber .50 protection level material for the purpose of evaluating a standard backing board and a light weight self-sealing material, Air Logistics 700SI-EN 2-41 and UniRoyal U.S. 182. There were two blocks, B29 and B30, in this series and these two differed in the skin spacing and skin material. B29 had a spacing of 1.25 inches with an 0.080 inch thick 2024-T3 aluminum clad skin. Block B30 had a spacing of zero inches with a 0.040 inch thick 6061-T6 aluminum skin. It was expected that this combination would perform well since it was made up of good quality board and self-sealing material. Experience has proven that occasionally the results from gunfire tests show a gross inconsistency. This series is an example of such a test.

(1) Block B29

This block received only one round, T37, at zero head pressure and straight-through entrance mode. The only expected result was a satisfactory entrance seal with a 0.30 inch high petal in the forward skin. The unexpected result was a tremendous fire ball (estimated 8 in. diameter) on entry causing a burned skin and backing board. On previous shots with this skin alloy, only a small fireball, if any, was observed at the entrance. No scorching had previously occurred. It is believed that the large fireball was caused by the presence of a volatile fuel vapor but not in a sufficient quantity to sustain the fire. The timely sealing of the entrance wound shut off any further supply of fuel for burning. Upon exit, the projectile was in a full tumbled position and cored the U.S. 182 material. The backing board failed at the point of impact and all fuel was lost through the wound. Figures H-5(a) and (b) show the neat projectile entrance through skin and backing board with the burned area noticeable on the board. Figure H-5(c) displays the cored aft panel with backing board splinters imbedded in outside material surface.

(2) Block B30

This block received four rounds (T58, T59, T60, T61), three straight and one tumbled, as a continuation of B29 to give the material combination further evaluation. Under identical conditions to B29 except for the skin type and clearance, marginal self-sealing capabilities emerged.

The first three, T58 through T60, straight-through rounds obtained entrance seals but only after considerable leakage. The tumbled round, T61, did not seal on the entrance, but did on the exit side. This round was fired at zero pressure.

The exit seals were just as marginal on the straight-through rounds, sealing only after some leakage but within military specification requirements. The seal achieved on tumbled round exit was good because of the absence of any coring which normally accompanies a full tumbled round.

Figure H-5(d) pictures the damage inflicted on the exit backing board. The ruptures are not large but appear to be shredded, thus losing support strength. Figures H-5(e) and (f) exhibit the clean entrance mode of all rounds and the severe petaling of the exit panels. This aft skin panel displays the extent of damage of skins placed adjacent to backing board. During this investigation, it was noticed that the skins mounted adjacent to backing boards showed a tendency to split while those with a gap tended to petal only. Examples of zero gap splitting are seen in blocks B27, B34, and B40. Examples of wider skin gap installations that petaled are B32, B29, and B37. This, no doubt, was due to the skin absorbing more energy from ram pressure the closer it was to the backing board.

f. Series 6

This series contained two blocks, B31 and B32, which were a further implementation of testing a light weight caliber .50 self-sealing material, UniRoyal U.S. 182, with a standard board, Firestone Fl-41. This test was to find any board that would consistently permit a potential marginal self-sealing material to perform satisfactorily.

Three straight-through rounds were fired in this series, T62 and T63 at zero head pressure, and T64 at 2 psig. Block B31 had a skin gap of 0.75 inches and B32 had a gap of 0.25 inches. B31 was an 0.040 inch thick 2024-T3 aluminum alloy skin and B32 had a 0.040 thick 6061-T6 aluminum alloy skin.

Entrance wounds caused by these three rounds sealed but exit wounds did not. The F1-41 backing board, therefore, showed no better support properties than others. This material, however, did show a great tendency to pull into the tank fixture body as a result of the rarefaction wave action. Figures H-6(a) and (b) show the damage left by a tumbled caliber .50 in the exit backing board and skin. In both photographs, the coring of the backing board is very plain. Figure H-6(c) shows the flow of fuel from the tank was a result of round T64.

g. Series 7

This series, consisting only of block B39, mated an experimental self-sealing material, Goodyear's DX325, and a medium duty standard self-sealing board, Conolite B33FG1W. This combination had a 1.25 inch skin gap with an 0.040 inch thick 2024-T3 aluminum alloy clad skin. For the one round fired, T66, an entrance seal was achieved but the exit side was a total failure, preventing further evaluation.

Figure H-6(d) and (f) are pictures of the aft skin and backing board damage. The large tear and coring of the backing board prevent support for the cell material. Figure H-6(e) is a close-up photograph of the DX325 material which shows a complete failure by the long tear present. This backing board, B33FG1W, manufactured by Conolite Corp., meets the requirements of MIL-P-8045, and is regarded in industry as a caliber .50 protection level material. In this test, this board split 18 inches vertically and cored leaving no support for the cell material causing the material to rip as shown in Figure H-6(e).

h. Series 8

This combination, B43, matches a standard board, Air Logistic 700SI-EN2-41, with an experimental self-sealing material, Goodyear's DX-325. This material was used also in B39. It was felt that further investigation of this material was needed because of the incomplete results of B39.

This configuration was a zero clearance setup with an 0.080 inch thick 2024-T3 aluminum alloy clad skin. This block, B43, received five rounds (T68, T69, T70, T71, T72) before the exit panel failed to seal. Acceptable seals were achieved on all entrance rounds. Round T68 was fired before it was discovered that Firestone F1146 self-sealing material had inadvertently been installed on the exit side. The exit panel was replaced with a DX-325 panel for the remainder of the shots. The DX-325 sealed satisfactorily in both fore and aft panels except for round T72. Figure

H-7(f) shows the exit board and the type of damage received from tumbling exit rounds. Figures H-7(a) and (b) are pictures of the skin panel and backing board that failed under round T68, the first one fired. Figures H-7(c) and (d) show the severe petaling and rolling that was found to be typical of skins mounted flush with backing board.

i. Series 9

This series combined a standard backing board, Conolite B33FG1W, with a standard .30 caliber sealing material, UniRoyal U.S. 179. Blocks B51 and B51.1 are that same configuration except that foam was installed in the tank for B51.1 to reduce fire hazard.

(1) Block B51

This block, B51, was a partial petaling setup with a 2024-T3 clad aluminum alloy skin which created a skin gap of 0.25 inches. Entrance seals were all satisfactory even though round T74 split whem tumbled. This splitting created two shrapnel-type entrance wounds as Figure H-8(a) and (d) show, indicating good sealing properties of this combination against shrapnel. Figure H-8(b) reveals a noticeable absence of rear panel damage because only one (T73) of the three rounds (T73, T74, T75) fired at this combination had an exit. The exit wound of T73 seeped constantly with just a trace of fuel when a head pressure of 2 psi was applied for the succeeding rounds T74 and T75. Figure H-8(d) shows the position of the incendiary striker plate located 18 inches from target face between target and aft velocity measuring screen. When this test combination was disassembled, it was found that all rounds hit the aft self-sealing panel but did no damage other than mark it.

(2) Block B51.1

T75 was a caliber .30 armor piercing incendiary round which acted no different than any AP round. The incendiary was burning at impact, but the foam installed in B51.1 apparently prevented fire or explosion inside the tank. This particular round did not exhibit the jagged, tearing effect on the materials as incendiary rounds normally have.

j. Series 10

This configuration matched Air Logistics 700SI-EN2-23 backing board and Goodyear FTL-13 self-sealing construction. The original block, B53, was shot with reticulated foam installed and a head pressure of 2 pounds per square inch. This setup was to check sealing properties under pressure.

A satisfactory entrance seal was achieved with T76, but a tumbled exit so damaged the aft panel that no sealing occurred, even after pressure was decreased to 0 psi, although leakage through the wound was at a reduced rate. Since it was necessary to disassemble the test fixture for repairs before continuing, it was decided to replace the reticulated foam with whiffle calls, Kent Manufacturing Co.'s voided balls numbered BTG-6. It was believed that action of these balls would aid tank sealing by performing a baffling action to realign self-sealing material walls.

With the whiffle balls installed, an entrance seal was achieved with round T78 but no exit seal was obtained. It could be easily seen that leakage was far greater with whiffle balls installed than with foam since fuel still sprayed from the wound after pressure was reduced to zero. After disassembly, whiffle balls were examined and all those that were contacted by the projectile were partially or completely destroyed. This condition prevented wall aligning action in the area of the wound, thus provided no aid to sealing.

Figure H-8(e) shows the backing board not supporting after round T76 (with foam installed) was fired. Figure H-8(f) shows the aft panel after round T78 was fired. At the time these photographs were taken, there was no internal pressure on the tank.

k. Series 11

This setup was tested to check on the support capability of Firestone's B-2 backing board, so this board was mated with a qualified self-sealing material, Firestone's 1146. This setup included a partial petaling created by a 7075-T6 aluminum alloy skin with a gap of 0.25 inches. It was thought that if petaling occurred at the entrance, the board would receive a severe test.

(1) Block B49

This block, B49, received round T77 with a straight-in entry mode. This skin cored instead of petaled on entrance, but a good entrance seal was still achieved. Total destruction of the aft panel occurred from the tumbled round and hydraulic ram pressure with no possibility of a seal. Figure H-9(a) shows entrance and H-9(b) shows failure of aft skin. Figure H-9(c) shows the fuel stream flowing from wound after two minutes at zero pressure. A close look at the aft backing board revealed an "X" shaped tear that left the tank no support. In this particular test, there was no evidence of sealant activation in the self-sealing material.

(2) Block B49.1

For firing B49.1, the entire exit panel installation was replaced, reticulated foam was installed, and round T79 was fired straight in under 2 psig tank pressure. As with T77, the entrance side sealed, but the exit failed to seal. The exit was in a tumbled mode. Skin destruction is shown in Figure H-9(d). The self-sealing material and backing board split with an estimated 5 gallons per minute leak resulting. Figure H-9(e) shows the aft panel removed and foam exposed. When a rarefaction wave is present, the foam displaces inward as the picture shows. This test also demonstrates that the damage resulting from T77 was much greater than T79 by comparing Figures H-9(b) and (d). The only configuration difference in the two rounds was the presence of foam for T79 which did visibly less damage.

l. Series 12

This configuration proved to be one of the most successful fired. This was a match of a heavy duty backing board, Air Logistics 700SI-EN2-61 (caliber .50 protection level) and a heavy duty .30 caliber self-sealing material, Firestone's 1316-3. This was a further effort to achieve petaling interference with a skin gap of 0.25 inches created by installing a 2024-T3 skin 0.040 inches thick. This particular setup sustained six hits (four caliber .30 and two caliber .50) in the straight-through and tumbled modes with two (T83, T85) being incendiary rounds, before it caught fire, thus ending the tests.

(1) Block B52

For the first three rounds, T80, T81, T82, which were all caliber .30, a good entrance seal under 2 psig pressure was achieved. Of these first three, only the first round (T80) had an exit. Even though the exit mode was a tumbled condition and backing board and self-sealant both had one inch splits, a good exit seal was obtained. Rounds T81 and T82, having no exit, did no damage to exit panels.

(2) Block B52.1

Round T83, caliber .30 AP incendiary, was fired after reticulated foam was installed and the skin clearance gap increased to 0.75 inches. This round not only had the jagged entrance that is typical of incendiary rounds, but because of the striker plate, entered full tumbled. No exit was obtained. There was a large flash on entry indicating the danger of fire, but with a damp seal achieved immediately and probable absence of volatile vapors, no fire occurred. Figure H-10(a) and (c) show the full tumbled tearing effect of the incendiary round on the entrance skin and backing board.

(3) Block B52.2

Round T84 was a straight-in, caliber .50 AP round, fired with the tank under 2 psig internal pressure. Good sealing under pressure resulted at entrance and exit giving evidence that a lower caliber self-sealing material seals well for higher caliber rounds when supported by a heavy duty backing board.

(4) Block B52.3

Round T85 was a caliber .50 AP incendiary round which was also fired into the test tank under 2 psig pressure. Due to the striker plate, this round entered partially tumbled, cored the skin and split the backing board. There was no entrance seal and the damage to backing board and self-sealing material can be seen in Figures H-10(c), H-11(a) and (b). A fire was ignited and burned externally only, mostly on the front side. Figure H-10(b) shows only a blackening of the aft backing board indicating little fire on the back side. Because of this indication, it was assumed that an exit seal was achieved, even though the round had a tumbled exit. Figure H-10(d) is a photograph of the entrance side after the fire was extinguished showing the small stream coming from the wound. Figures H-10(e) and (f) show the first layer of foam entered by the burning incendiary round. The outside surface is not burned, but when the piece was cut open (Figure H-10(f)) a burned area was found to exist. This was probably from the incendiary burning out in the presence of the fuel. The fuel leak at the entrance was not one of disastrous proportions, but the accompanying fire probably would have been.

m. Special Materials

During the course of this investigation, several untried and unqualified materials were examined. These new materials or concepts would have some possible use in aircraft fluid systems protection for integral or metal tanks.

(1) The first of the special materials tested was an elastomeris resin, HC1101, produced by 3M Company. Only one caliber .30 round, T1, was fired, straight-in, into this material. Since this material was thick, 0.375 inch, no skin or backing board was installed with it. The entrance panel sealed very well under zero pressure, but the exit panel failed completely. It is believed that the ram pressure wave, not the projectile, broke the aft panel. Figure H-11(c) and (d) show the entrance and exit damage.

(2) One of the more successful sealants tested was the Goodyear Tire and Rubber Co.'s "Vithane", FLC-1, rubber coating. This coating, 0.375 inches thick, was bonded to a 0.040 inch thick 7075-T6 bare aluminum panel. The panel received four straight-through rounds, three caliber .30 rounds, and one caliber .50, before a failure occurred. The three caliber .30 rounds (T2, T3, T4) were shot at 0, 1, and 2 psig and the caliber .50 at zero psig. Good seals were achieved on all entrances. The caliber .30 rounds did not exit, but did dent, pierce, crack, and petal the aft skin, but in so doing did not cause aft panel leakage. The caliber .50 round, T5, exited in the tumbled mode, cored both skin and coating material to such an extent that no sealing occurred. This non-sealing condition was aided by petaling of the aft skin as seen in Figure H-11(f). Figure H-11(e) shows the fuel side of the entrance panel and the good seals obtained. In this application, this coating seemed to increase the structural integrity of the material to which it was bonded.

(3) Air Logistics provided three defense composites for test, and these were shot in blocks B9, B13, B48 and B48.1. These composites would be exterior surface protection methods for fuel or oil systems.

In B9, four caliber .30 AP rounds, three straight-in and one tumbled, were fired into Air Logistics' composite 114509-217. This composite is made of a rubber sealant placed between two "Stratoglas" backing boards. The outside board is not bonded to the rubber and thus performs the function of an ordinary backing board. Three straight-in rounds sealed on entrance, but all exits failed. Neither the entrance nor exit sealed on the tumbled round.

Block B14 received three straight and two tumbled caliber .30 AP rounds. This composite, 114509-102, differed from B9 composite only in that both boards were bonded to the sealing rubber. This had no apparent effect on the sealing properties because only the entrance side of straight-in rounds sealed satisfactorily.

Blocks B48 and B48.1 were tests of Air Logistics 114509-304 defense composite. This was a backing board - rubber sealant combination bonded to a reinforced skin panel. This composition was representative of an integral fuel cell with the sealant - backing board combination bonded to an exterior skin surface. Only one of these panels was used on the forward side of the test fixture. On the aft side, Air Logistics' board 700SI-EN2-41, Goodyear's DX-325 self-sealing material, and a skin panel with a 0.75 inch skin gap were installed.

Three caliber .30 AP (T32, T33, T34), two straight-in and one tumbled, had good entrance seals, but did not exit through the back panel. Rounds impinged on the aft material (DX-235) but did not cause any leakage. The first straight-through caliber .50 AP , T35, sealed dry on entrance and exit side sealed in three minutes. The next caliber .50 AP round (T36) was a tumbled entry which separated the skin and self-sealing rubber, cored the backing board, and buckled the front panel. There was no seal on forward panel. On the aft side, nose of projectile embedded in skin after passing through aft self-sealing material and backing board, but a dry seal was achieved.

Figures H-12(a) and (b) show the outside and fuel side of the -304 composite and the extent of damage. Figure H-12(c) shows the damage to the exit side backing board by both caliber .30 and .50 rounds as numbered in preceding paragraph.

SECTION VII

CONCLUSIONS

1. LITERATURE SEARCH AND VENDOR SURVEY

The results of the literature search and vendor survey portion of this study, as outlined in Section IV of this report, form the basis for the following conclusions:

a. Little or no useful published information exists which would assist the designer of future military aircraft in developing an efficient self-sealing fuel tank installation.

b. Numerous published works are available which provide academic interest and background information on the phenomena of ballistic damage to fuel tanks.

c. No consistent design criteria has apparently been used in the past for self-sealing fuel tank installations.

d. Skin to backing board gaps in past installations have apparently been dictated by structural requirements without regard for the penalties incurred, such as fuel volume loss and increased fire hazard.

e. Little use is made of protective methods other than self-sealing fuel tanks.

f. No data was obtained on performance of self-sealing installations under combat.

2. DRY SKIN GUNFIRE TESTS

Several conclusions may be drawn from the results of the dry skin gunfire tests, outlined in Section V of this report. These conclusions include the following:

a. Tumbled entrance penetrations will cause coring of skin materials and will create more destructive effect than straight-in entrance penetrations.

b. Flashes of fire on the entrance surface can occur at normal projectile velocities under 3000 feet per second and when either .30 caliber or .50 caliber projectiles are used, depending on the material of the skin.

c. Use of more ductile skin materials, 2024-T3 and 6061-T6 versus 7075-T6 or Titanium alloy, can reduce the probability of creating flashes of fire on entrance penetrations.

d. More ductile materials, such as 2024-T3 and 6061-T6, produce greater petal height when penetrated than less ductile alloys, 7075-T6 or Titanium.

e. Lower velocity projectiles create significantly greater petal height than high velocity projectiles, regardless of skin material.

3. WET TANK GUNFIRE TESTS

The wet tank gunfire tests, described in Section VI of this report, formed the major part of this study. The conclusions drawn from the results of the wet tank gunfire tests are as follows:

a. Internal pressure during testing reduces the probability of a satisfactory seal, particularly on exit penetrations.

b. The extensive hydraulic ram pressure developed within a fuel tank by the entrance of a ballistic projectile must be attenuated by an elastic "working" support structure or by the use of some energy absorbing device in the tank. Gross structural damage and failure of the tank material to seal will occur if no provision is made for dissipating this pressure.

c. Tumbled projectile entrances and exits produce wounds with less probability of satisfactory sealing, primarily because of coring out of sealant, than wounds produced by straight-in projectile entrances and exits

d. The results of these tests do not support the theory that petaling of skins due to projectile penetration will prevent satisfactory sealing when the skin is in intimate contact with the backing board/self-sealing material combination. Entrance penetrations through such intimate sandwich buildups should perform satisfactorily, regardless of entrance mode. Exit penetrations are subject to gross structural damage caused by the internal hydraulic ram pressure in the tank. Satisfactory sealing may still be obtained as long as the support from the backing board is not destroyed.

e. Reticulated polyurethane foam installed inside fuel tanks serves as an excellent suppressant for internal fire and/or explosion.

f. Reticulated polyurethane foam installed inside fuel tanks will have no apparent effect on sealing capability of the tank material, although some reduction in leakage rate was observed.

g. The use of perforated hollow plastic spheres (whiffle balls) inside fuel tanks will have no effect on sealing capability of the tank material. Based on limited testing, foam appears to have more influence on sealing ability and leakage rate than whiffle balls.

h. Heavy backing boards should perform better, in all cases, than lighter, more flexible backing boards. In particular, heavier backing board can improve the performance capability of .30 caliber self-sealing material against .50 caliber projectiles.

i. Effective sealing appears to be directly proportional to the thickness and unit weight of the self-sealing material when used with comparable backing boards.

j. Optimum combinations of backing board and self-sealing materials can be obtained only by dynamic testing, i.e., gunfire.

k. Although excessive hydraulic ram pressures were encountered, comparisons of material performance would not have differed significantly if a structure more representative of aircraft structure had been used.

l. Based on the high percentage of entrance seals recorded in Table II, all of the materials tested should seal satisfactorily when subjected to a projectile fired in a straight in mode.

m. The following materials performed satisfactorily in all entrance modes and should perform acceptably in service use:

(1) Backing Boards

(a) Conolite Corp. B33FG1W

(2) Self-sealing Materials

(a) Goodyear Tire and Rubber Co. DX325 and FTL-13

(b) UniRoyal U. S. 179 and U. S. 182.

n. The following materials, listed in alphabetical order, showed evidence of superior performance and should perform well in service use:

(1) Backing Boards

(a) Air Logistics 700SI-EN2-23, -EN2-41, and -EU1-61

(b) Goodyear Aerospace Corp. ARM 018 and ARM 1800.

(2) Self-sealing Materials

(a) Firestone Tire and Rubber Co. 1316-3

(b) Goodyear Tire and Tubber Co. FTL 11-3 and FLC-1

(c) UniRoyal, Inc. (U. S. Rubber) U. S. 173 and U. S. 180.

o. Based on the results of this test program, M. C. Gill Corporation laminates, Gillfab 1068 and 1075, do not appear suitable for use as backing boards for self-sealing fuel tanks because of lack of structural integrity under ballistic impact. Similarly, 3M material HC 1101 does not appear to be satisfactory for sealing where high impact pressures may be experienced because of lack of structural integrity.

The following materials were not tested sufficiently to reach a conclusion, or the test results were inconclusive:

(1) Backing Boards

(a) Firestone Tire and Rubber Co. B-2 and F1-41.

(2) Self-sealing Materials

(a) Firestone Tire and Rubber Co. 1146

(3) Defense Composites

(a) Air Logistics 114509-102, 114509-217, and 114509-304

4. GENERAL CONCLUSIONS

Existing materials, some of which have not yet been qualified, can provide satisfactory protection for aircraft fuel tanks when properly utilized. The apparent key to success of use lies in the complete integrated design of the system from inside the tank to structural materials and support outside the tank.

APPENDIX A

MATERIAL MANUFACTURERS QUESTIONNAIRE

VOUGHT AERONAUTICS DIVISION

LTV AEROSPACE CORPORATION

P.O BOX 5907
DALLAS, TEXAS 75222

2-51723/7L-1453

Attn:

Subj: Request for Information on Materials for Protection of Aircraft Fluid Systems from Ballistic Damage

Encl: (1) Questionnaire on Protective Materials for Aircraft Fluid Systems

The Vought Aeronautics Division of LTV Aerospace Corporation is currently under contract (No. F33615-67-C-1673) with the Air Force Materials Laboratory, Wright-Patterson Air Force Base, to evaluate methods and materials for protecting aircraft fluid systems from ballistic damage. This program is of vital interest to the military as a result of recent involvement in Southeast Asia.

The initial phase of this program involves the accumulation of information on protective methods and materials. The program will also include .30 and .50 caliber gunfire tests on selected materials and concepts for self-sealing fuel tanks. The gunfire test program is presently scheduled to begin the first week in September.

We are requesting your assistance in this program by providing the Air Force with the latest information on protection techniques and materials pertaining to protection of aircraft fluid systems. Specifically, we would welcome any information you can provide on products that your firm manufactures, has manufactured in the past or has presently in development that may have application to protection system design. The Air Force is particularly interested in the qualification status and the type of qualification test employed for each of the materials. If new materials are under development, the Air Force is interested in knowing the projected protection level and earliest date when the material is anticipated to be available for test and evaluation by personnel outside your company.

To guide you in the type of information desired, we have prepared a questionnaire which we sincerely hope you will complete and return. These questionnaires are also being sent to other manufacturers of various types of protective materials. Similar questionnaires have also been prepared for completion by airframe manufacturers to determine what experience they have had with protecting aircraft fluid systems.

Subj: Request for Information on Materials for Protection of Aircraft
Fluid Systems from Ballistic Damage

We would also appreciate any test reports you might provide on either permanent or temporary loan basis that would help us in developing a meaningful test program for evaluating the materials which we plan to test later in the program. Titles and sources of reports not currently in your possession would also be of value to us.

Because of the urgent need for the results of this evaluation, we would appreciate it if you would send us whatever information you can provide within ten days if at all possible. We will treat information you send us as Private if requested. The results of this program will be summarized in a final report which we now anticipate will be classified and whose distribution will be established by the Air Force; however, we will recommend to the Air Force that your organization be placed on the distribution list. In any case, we will be pleased to send you the results of our gunfire tests of all of your materials that are included in our test program.

The principal investigator on this program, Mr. J. M. Metcalf, will be happy to discuss with you any aspect of this program that will result in bringing to the Air Force's attention the most promising concepts for protection of aircraft fluid systems. Mr. Metcalf's address is as follows:

Vought Aeronautics Division
LTV Aerospace Corporation
P. O. Box 5907
Dallas, Texas 75222

Attn: J. M. Metcalf
Unit 2-51723

We would like to thank you in advance for whatever information you can provide that will help the Air Force solve what they consider to be one of the most important problems in Southeast Asia today.

Yours truly,

G. A. Starr
Chief, Applied Research and Development

GS/mc

SURVEY OF MATERIALS FOR PROTECTION OF
AIRCRAFT FLUID SYSTEMS FROM BALLISTIC DAMAGE

1. Name of manufacturer: ____________________

2. Material category: Self-sealing tanks ________
   Self-sealing hose ________
   Self-sealing tubes ________
   Backing board ________

3. Material identification or part number ____________

4. Fluid media protected: JP-4 Fuel ________
   JP-5 Fuel ________
   Hydraulic Oil ________
   Lube Oil ________

5. Applications: Is this material currently in use by any aircraft manufacturer? Yes ______ No ______

   If yes, please list applications below:

   Aircraft   Manufacturer

   ____

6. Protection level: What is the protection level of this material? List military specifications if applicable. ____________

7. Production status: Is this material now being produced? yes ______ no ______ If no, when was material last produced? ________

8. Qualification status: Has this material been qualified and accepted to a military specification? ________ When? ________ Where? ____

9. Temperature Range: For what temperature range is this material qualified? Ambient ________ Fluid ________

10. Handling: Does this material require special handling in excess of normal military usage? yes ______ no ______ If yes, please explain briefly. ____________

11. Storage: Does this material require any special storage facilities in addition to requirements of the applicable military specifications? yes ________ no ________ If yes, please explain briefly. ____________

12. Life: Does this material have any characteristics which would give it less than a normal life-span? yes ______ no ______ If yes, please explain briefly. ____________

13. Maintenance: Does this material require any maintenance tasks? yes ________ no ________ If yes, please explain briefly.

____

14. Repair: Is this material reparable? yes ________ no ________ If so, please state briefly the type of repairs or procedure.

____

15. Restrictions on Usage: Are there any restrictions on installation of this material in aircraft or other vehicles? yes ________ no ________ If yes, please explain briefly. ________

16. Historical Data: Do you know of any historical data of crash or battle damage that would be useful in the evaluation of this or similar materials? yes ________ no ________

If yes, can this material be made available to VAD, either permanently or on loan, for use on this evaluation? ________

If so, please advise VAD of means of obtaining this data. ________

17. Weight: What is the weight/sq ft of this material? ________

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APPENDIX B

AIRFRAME MANUFACTURER QUESTIONNAIRE

VOUGHT AERONAUTICS DIVISION

LTV AEROSPACE CORPORATION

P O BOX 5907
DALLAS, TEXAS 75222

2-51723/TL-1452

Attn:

Subj: Request for Information on Use of Materials for Protection of Aircraft Fluid Systems from Ballistic Damage

Encl: (1) Questionnaire on Use of Protective Materials for Aircraft Fluid Systems

The Vought Aeronautics Division of LTV Aerospace Corporation is currently under contract (No. F33615-67-C-1673) with the Air Force Materials Laboratory, Wright-Patterson Air Force Base, to evaluate methods and materials for protecting aircraft fluid systems from ballistic damage. This program is of vital interest to the military as a result of recent involvement in Southeast Asia.

The initial phase of this program involves the accumulation of information on protective methods and materials. The program will also include .30 and .50 caliber gunfire tests on selected materials and concepts for self-sealing fuel tanks. The gunfire test program is presently scheduled to begin the first week in September.

We are requesting your assistance in this program by providing the Air Force with the latest information on protection techniques and materials pertaining to protection of aircraft fluid systems. Specifically, we would welcome any information on your experiences with protective materials and methods used in aircraft that you manufacture, problems that you might have had in the use of these materials, tests that you may have performed, and conclusions regarding the effectiveness of the materials used.

To guide you in the type of information desired, we have prepared a questionnaire which we sincerely hope you will complete and return. These questionnaires are also being sent to other airframe manufacturers for their comments on their experience with these materials. Similar questionnaires have also been prepared for completion by manufacturers of protective system materials to determine what materials are currently being developed for applications such as protecting aircraft fluid systems.

2-51723/7L-1452

Subj: Request for Information on Use of Materials for Protection of Aircraft Fluid Systems from Ballistic Damage

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We would also appreciate any test reports you might provide on either permanent or temporary loan basis that would help us in developing a meaningful test program for evaluating the materials which we plan to test later in the program. Titles and sources of reports not currently in your possession would also be of value to us.

Because of the urgent need for the results of this evaluation, we would appreciate it if you would send us whatever information you can provide within ten days if at all possible. We will treat the information you send us as Private if requested. The results of this program will be summarized in a final report which we now anticipate will be classified and whose distribution will be established by the Air Force; however, we will recommend to the Air Force that your organization be placed on the distribution list.

The principal investigator on this program, Mr. J. M. Metcalf, will be happy to discuss with you any aspect of this program that will result in bringing to the Air Force's attention the most promising concepts for protection of aircraft fluid systems. Mr. Metcalf's address is as follows:

Vought Aeronautics Division
LTV Aerospace Corporation
P. O. Box 5907
Dallas, Texas 75222

Attn: J. M. Metcalf
Unit 2-51723

We would like to thank you in advance for whatever information you can provide that will help the Air Force solve what they consider to be one of the most important problems in Southeast Asia today.

Yours truly,

G. A. Starr
Chief, Applied Research and Development

GS/mc

SURVEY OF AIRFRAME APPLICATIONS OF
MATERIALS FOR PROTECTION OF AIRCRAFT
FLUID SYSTEMS FROM BALLISTIC DAMAGE

1. Name of airframe manufacturer ______________________________

2. Aircraft identification ______________________________

3. Types of protection provided:

	Yes	No
Self-sealing fuel tanks		
Self-sealing hose		
Self-sealing tubes		
Self-sealing oil tanks		
Armor		

4. Fluid media protected:

	Yes	No
JP-4 Fuel		
JP-5 Fuel		
Hydraulic Oil		
Lube Oil		

5. Please answer the following for self-sealing fuel and/or oil tanks: (Please complete additional copies for each different construction used)

   (a) Manufacturer's Name ____________
   (b) Manufacturer's Construction Identification ____________
   (c) Protection Level ____________
   (d) Backing Board ____________
   (e) Nominal spacing from structure ____________
   (f) Type of structural support ____________

6. Please answer the following for self-sealing hose or tube:

   (a) Manufacturer's Name ____________
   (b) Manufacturer's Construction Identification ____________
   (c) Protection Level ____________
   (d) Line operating pressure ____________
   (e) What made you select this over other alternatives? ____________

7. Have you experienced any difficulties or limitations in applications, such as environment, which would influence your use of this type of material in the future? yes __________ no __________

   If yes, please explain briefly: ______________________________

8. Have you encountered penalties in structure to support these materials which would influence aircraft design, particularly in terms of additional weight or cost? yes __________ no ______

   If yes, please explain briefly: ______________________________

VOUGHT AERONAUTICS DIVISION

LTV AEROSPACE CORPORATION

P.O. BOX 5907
DALLAS, TEXAS 75222

2-51723/7L-1690

Attn:

Subj: Request for Information on Materials for Protection of Aircraft Fluid Systems from Ballistic Damage

Encl: (1) Questionnaire on Protective Materials for Aircraft Fluid Systems
(2) Questionnaire on Use of Protective Materials for Aircraft Fluid Systems

The Vought Aeronautics Division of LTV Aerospace Corporation is currently under Contract (No. F33615-67-C-1673) with the Air Force Materials Laboratory, Wright-Patterson Air Force Base, to evaluate methods and materials for protecting aircraft fluid systems from ballistic damage. This program is of vital interest to the Military as a result of recent involvement in Southeast Asia.

The initial phase of this program involves the accumulation of information on protective methods and materials. The program will also include .30 and .50 caliber gunfire tests on selected materials and concepts for self-sealing fuel tanks. The gunfire test program is presently scheduled to begin the first week in September.

We are requesting your assistance in this program by providing the Air Force with the latest information on protection techniques and materials pertaining to protection of aircraft fluid systems. Specifically, we would welcome any information you can provide on products that you have been associated with in the past or on any item you now have under test or examination. The Air Force is particularly interested in the qualification status and the type of qualification test employed for each of these materials.

To guide you in the type of information desired, we have prepared two questionnaires which we mailed to materials manufacturing firms and airframe manufacturers. These questionnaires, enclosures (1) and (2), are for reference, if you wish, or for use by you in the transfer of any information to us. We would appreciate any test reports you might provide on either permanent or temporary loan basis that would help us in developing a meaningful test program for evaluating the materials or protection devices which we plan to test later in the program. Titles and sources of reports not currently in your possession would also be of value to us.

2-51723/7L-1690

Subj: Request for Information on Materials for Protection
of Aircraft Fluid Systems from Ballistic Damage

Because of the urgent need for the results of this evaluation, we would appreciate it if you would send us whatever information you can provide within ten days if at all possible. The results of this program will be summarized in a final report which we now anticipate will be classified and whose distribution will be established by the Air Force. In this manner, the report will be available to all concerned through Air Force distribution.

The principal investigator on this program, Mr. J. M. Metcalf, will be happy to discuss with you any aspect of this program that will result in bringing to the Air Force's attention the most promising concepts for protection of aircraft fluid systems. Mr. Metcalf's address is as follows:

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Attn: Mr. J. M. Metcalf
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We would like to thank you in advance for whatever information you can provide that will help the Air Force solve what they consider to be one of the most important problems in Southeast Asia today.

Yours truly,

G. A. Starr
Chief, Applied Research and Development

GS/mc

APPENDIX C

BIBLIOGRAPHY

BIBLIOGRAPHY

This bibliography is in three parts. Part I covers reports available in the VAD Technical Library. The time period covered in Part I is indefinite. Part II covers reports which may be ordered from Defense Documentation Center. The timer period covered in Part II is the last 3-1/2 years. Abstracts of most Part II reports may be reviewed in the Library copies of the TAB (Technical Abstract Bulletin). Copies of reports in Part II may be ordered through the Library. Part III covers reports taken from other references in the field of the search. Part III reports may be ordered from the originating company through the Library.

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U. S. Army, Ballistic Research Labs. Conf. June 1958

22. Gunfire Damage Evaluation of Fuel Tank Designs,
U. S. Air Force, WADC. April 1957

23. Design of Military Aircraft for Minimum Vulnerability, Pt. III, (U)
U. S. NADC. Conf. December 1954

24. Fuel Tank Fire and Explosion Suppression System Development.
U. S. Air Force, WADC. November 1956

25. Compartmented Fuel Tanks.
U. S. Air Force, WADC. November 1953

26. Inerting Conditions for Aircraft Fuel Tanks
U. S. Air Force, WADC. September 1955

27. Gunfire Qualification Test of the Model F9F-6 Airplane Self-Sealing Fuel Cell Installation. U. S. Naval Proving Ground

28. Gunfire Qualification Test of Model F2H-3 Airplane Fuselage Self-Sealing Fuel Cell Installation. U. S. Naval Proving Ground. December 1952

29. Gunfire Evaluation of Purge Mats. U. S. A Force, WADC. September 1955

30. Gunfire Tests of Model A3D-1 Airplane Fuselage Self-Sealing Fuel Cell Installations. U. S. Naval Proving Ground. December 1954

31. Fuel Tank Firing Test. Douglas Aircraft. May 1946

32. High-Survivability Aircraft Design Principles: A Close-Support Aircraft Example Design (U). Rand Corp. Secret. December 1966

33. AD-351289. Studies in Armor Penetration, (U). Armament Research and Development Establishment (Canada). Secret. Jan 64

34. AD-363861. Vulnerability of Helicopters in South Vietnam, (U). U. S. Air Force, TAC. Secret. July 1965

35. AD-362625L. Dual-Hardness Steel Armor, (U) U. S. Army, Materials Research Agency. Secret. June 1965

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1. AD-377571L. Non-Conventional Armor Research, (U) Budd Co. Secret. Summary Report, Jun 63 thru Sept 66. September 1966

2. AD-377196L. A Compilation of Existing Vulnerability Data of Selected U. S. Military Aircraft, (U). NADC, Johnsville, Air Warfare Research Dept. Secret. October 1966

3. AD-376923. Correlations of Aircraft Hit Data in South Vietnam (U) Ballistic Research Labs. Conf. March 1966

4. AD-376648L. Development of Heat-Treated Composite Steel Armor (U) U. S. Steel, Applied Research Lab. Conf. October 1966

5. AD-376494. The Characteristics and the Lethality of Particles Formed During the Perforation of Steel Armor by Steel Fragments (U). John Hopkins U. Secret. September 1966

6. AD-376542L. Non-Conventional Armor Research (U). Budd Co. Secret. July 1966

7. AD-376262L. Information for Selection of Lightweight Armor Materials for Aircraft (U). Goodyear Aerospace Corp. Secret. September 1966

8. AD-800200. USAF Guide to Parasitic Armor Installation. AF Flight Dynamics Lab. Uncl. September 1966.

9. AD-486902. Fire and Explosion Hazard Assessment and Prevention Techniques for Aircraft. Bureau of Mines, Pittsburgh. Uncl. June 1966

10. AD-374736L. Non-Conventional Armor Research (U). Budd Co. Secret. May 1966

11. AD-374333. Aircraft Damage and Casualties from Ground Fire in South Vietnam Operations (U). Ballistic Research Labs. Conf. June 1966

12. AD-486034L. Armor Team Visit to Vietnam, 14 February - 4 April 1966. Army Materiel Command. Uncl. April 1966

13. AD-374397. Composite Aircraft Armor Materials Research and Development (U) Goodyear Aerospace Corp. Conf. March 1966

14. AD-347271L. Non-Conventional Armor Research (U). Budd Co. Secret. March 1966

15. AD-374334. Ballistic Behavior of Ceramic Composite Armors (U). Army Materials Research Agency. Secret. June 1966

16. AD-374350. A New Concept in Lightweight Armor - Dual Hardness Steel (U). Army Materials Research Agency. Secret. June 1966

17. AD-374359L. Non-Conventional Armor Research (U). Budd Co. Secret. April 1966

18. AD-635482. The Effect of Deformation Processing on the Mechanical Properties of TI-6Al-4V for Armor. Titanium Metals Corp. Uncl. June 1966

19. AD-485433L. Non-Metallic Bullet Sealing. Army Tank-Automotive Center. Uncl. September 1951

20. AD-373247L. Study of Aircraft Fuel Protection Systems (U). Falcon Res. & Dev. Co. Secret. April 1966

21. AD-372605L. Parametric Design Study, Ballistic-Resistant Aircraft Components (U). Goodyear Aerospace Corp. Secret. March 1966

22. AD-482305L. A-7 Armor Kit Compatibility Tests. NATC, Pax River, Uncl. May 1966

23. AD-372255 L. Engineer Design Test of Armor, Ceramic Composite Plate, Manufactured by GMC, B-60 (U). Dev. & Proof Services, Aberdeen Proving Ground. Secret. May 1966.

24. AD-482033. Fire and Explosion Hazard Assessment and Prevention Techniques for Aircraft, Bureau of Mines, Explosives Research Center. Uncl. Mar 66

25. AD-371961L. Optimization of Armor Protection Coverage for Army Aircraft Aircrews (U). Goodyear Aerospace Corp. Conf. March 1966

26. AD-371969. Vulnerability of the Light Observation Helicopter (OH-6A) and Suggested Methods to Reduce Its Vulnerability (U) Ballistic Research Labs. Conf. September 1965

27. AD-371985L. Limited Observations on Vulnerability of Air Mobile Forces(U) Combat Operations Research, Ft. Belvoir. Conf. January 1963

28. AD-631610. Aircraft Fuel Tank Design Criteria. Aviation Safety Engineering and Research, Phoenix. Uncl. March 1966

29. AD-371336. Composite Aircraft Armor Materials Research and Development (U) Goodyear Aerospace Corp. Conf. January 1966

30. AD-371413L. Non-Conventional Armor Research (U). Budd Co. Secret. February 1966

31. AD-480398. Ballistic Behavior of Adhesively Bonded Honeycomb Aluminum Panels for a High-Performance Aircraft. Technical Operations, Inc. Uncl. March 1966

32. AD-370967. Correlations of Aircraft Hit Data in Vietnam (U). Ballistic Research Labs. Conf. September 1965

33. AD-370387L. Vulnerability and Survival of OV-10A Aircraft Encountering Weapon Systems of Their Operating Environment (U) Peat, Marwick, Caywood, Schiller & Co. Secret. December 1965

34. AD-370794L. Exploratory Development and Fabrication of Lightweight Composite Aircraft Armor Materials (U). Norton Co., Worcester, Mass. Secret. September 1964

35. AD-370512L. Non-Conventional Armor Research (U) Budd Co. Secret. January 1966

36. AD-369925. The Current Status of Pellet Technology and Its Effect Upon Vulnerability Analysis (U). Aerospace Corp., El Segundo. Conf. Feb 66

37. AD-369756L. Non-Conventional Armor Research (U). Budd Co. Secret. December 1965

38. AD-477232. Detection and Measurement of Inflammable Vapours Aircraft. Royal Aircraft Establishment, Farnborough. Uncl. September 1965.

39. AD-369394. Ceramic-Fiber Metal Composite Armor (U). IIT Research Inst. Conf. January 1966

40. AD-369416L. Non-Conventional Armor Research (U). Budd Co. Secret. November 1965

41. AD-369081. Preliminary Aircraft Vulnerability Testing (U). Air Proving Ground Center, Eglin AFB. Conf. November 1965

42. AD-368932L. Non-Conventional Armor Research (U). Budd Co. Secret. October 1965

43. AD-368088L. Non-Conventional Armor Research (U). Budd Co. Secret. September 1965

44. AD-368255. Siliceous Cored Armor-A Critical Review (U). Watertown Arsenal. Conf. June 1956.

45. AD-368258. Evaluation of a Magnesium-Lithium Alloy for Lightweight Armor Applications (U). Watertown Arsenal. Conf. July 1958.

46. AD-474887L. Fleet Operational Investigation of a Surveillance Type Fire Detection System. Operational Test and Evaluation, Norfolk. Uncl. July 1962

47. AD-474994L. Research Test of Techniques for Evaluation of Welded and Light Armor Material. Dev. & Proof Services, Aberdeen. Uncl. Dec. 1965

48. AD-367268. An Analysis of the Cumulative Effects of Multiple Hits on a Target (U). Ballistic Research Labs. Conf. July 1965

49. AD-367317. Composite Aircraft Armor Materials Research and Development(U) Goodyear Aerospace Corp. Conf. September 1965

50. AD-367008L. Non-Conventional Armor Research (U). Budd Co. Secret. May 1965

51. AD-367009L. Non-Conventional Armor Research (U). Budd Co. Secret. June 1965

52. AD-367010L. Non-Conventional Armor Research (U). Budd Co. Secret. July 1965

53. AD-367011L. Non-Conventional Armor Research (U). Budd Co. Secret. August 1965

54. AD-366960L. State-of-the-Art Study on Armor Materials Applicable to Modular Construction(U). Battelle. Secret. October 1965

55. AD-367071L. Ceramic Composite Armors (U) Army Materials Research Agency. Secret. October 1965

56. AD-367091L. Component Development Test of Aircraft Armor Materials (Ballistic Evaluation of Composite Armor Configurations) Dev. & Proof Services, Aberdeen. Conf. November 1965

57. AD-472578. Evaluation of an Intumescent Paint as a Fire-Retardant Covering. Picatinny Arsenal. Uncl. October 1965.

58. AD-621246. Armor Materials Research. Part I. Proceedings of a Meeting of Armor Materials Research Contractors, 19-20 May 1964. Army Natick Labs. Uncl. August 1965

59. AD-365832L. Non-Conventional Armor Research (U) Budd Co. Secret. March 1965

60. AD-365833L. Non-Conventional Armor Research (U) Budd Co. Secret. April 1965

61. AD-366024. Armor Materials Research. Part II. Proceedings of a Meeting of Armor Materials Research Contractors, 19-20 May 1964 (U). Army Natick Labs. Conf. June 1965

62. AD-365069. Composite Aircraft Armor Materials Research and Development (U) Goodyear Aerospace Corp. Conf. July 1965

63. AD-363383L. CH-34 Component Armor Protection System Design (U) Sikorsky Aircraft. Conf. June 1965

64. AD-363412. Improved Modular UH-1 Armor System (U) Goodyear Aerospace Corp. Conf. July 1965

65. AD-467232L. Screening Test Program for Evaluation of the Stress Corrosion Susceptibility of Alloys Under Consideration for Application as Skin Material. Douglas Aircraft. Uncl. July 1963

66. AD-362956L. Test Results, Environmental and Ballistic Evaluation of HFC Armor for CH-34 Helicopter (U). Goodyear Aerospace Corp. Conf. Mar 1965.

67. AD-362260L. Fundamental Material Properties Effects on Ballistic Protection of Lightweight Ceramic Composite Armor (U). Army Materials Research Agency. Secret. April 1965

68. AD-362389. Development of Reinforced Plastic Backing for Ceramic-Faced Composite Armor (U). Picatinny Arsenal. Secret. July 1965

69. AD-362430L. Armor-Module Design (U). Battelle. Conf. May 1965

70. AD-362431L. Supplementary Tables for Report No. BAT-171-23, "Armor-Module Design" (U). Battelle. Secret. May 1965

71. AD-362080. Vulnerability of UH-2A Helicopters - Armor Protection and Its Effect on Mission Survival (U). NADC, Johnsville. Conf. July 1963

72. AD-362034L. Tactical Aircraft Vulnerability/survivability (AV/S) in Varying Combat Situations.(U) North American. Secret. May 1965

73. AD-361161L. Engineer Design Test of Cast Armor, Thin Gage Versus Small Arms (Ballistic Evaluation) (U). Dev. & Proof Services, Aberdeen

74. AD-360764. Proceedings of Symposium on Lightweight Armor Materials, Held at Army Tank-Automotive Center, Warren, Michigan, November 5-6 1964 (U) Army Materials Research Agency. Secret. March 1965.

75. AD-360016L. Engineer Design Test of Ribbed Cast Armor (Ballistic Evaluation) (U). Dev. & Proof Services, Aberdeen. Conf. April 1965

76. AD-359083L. Vulnerability of HUS-1 Helicopters - Armor Protection and Its Effect Upon Mission Survival (U). NADC, Johnsville. Secret. February 62

77. AD-358892L. Non-Conventional Armor Research (U) Budd Co. Secret, January 1965

78. AD-358892L. Non-Conventional Armor Research (U) Budd Co. - Secret - January 1965

79. AD-358893. The Characteristics of Particles Formed During the Perforation of Steel Armor by Steel Frawments (U)
Ballistic Analysis Lab., John Hopkind

80. AD-358898L. Non-Conventional Armor Research (U)
Budd Co. Secret February 1965

81. AD-358985. Aircraft Armor Technical Summary Report (U)
Dev. & Proof Services, Aberdeen

82. AD-359-084L. Engineer Design Test of Ribbed Cast Armor (Versus Attack by Various Projectiles) (U) Dev. & Proof Services, Aberdeen. Conf. March 1965

83. AD-459345. Correlation of Tensile Properties and Ballistic Performance of Reinforced Plastics
Picatinny Arsenal. Uncl. March1965

84. AD-358229. Ballistic Limit Evaluation of Armor Attacked by Flechettes (U)
Ballistic Research Labs. (U) Conf. November 1960

85. AD-357606. Summary of Supporting Investigation on Small Caliber Armor-Piercing Ammunition (U). Frankford Arsenal. Conf. November 1964

86. AD-456886L. Use of Intumescent Paint Coating on Aircraft.
NAEC, Philadelphia. Uncl. February 1965

87. AD-357244L. Non-Conventional Armor Research (U).
Budd Co. Secret. December 1964

88. AD-367421. Titanium Alloy Armor (U). Watertown Arsenal. Conf. August 59

89. AD-356898L. Non-Conventional Armor Research (U)
Budd Co. Secret. September 1964

90. AD-356954L. Non-Conventional Armor Research (U)
Budd Co. Secret. August 19

91. AD356955L. Non-Conventional Armor Research (U)
Budd Co. Secret. October 1964

92. AD-356956L. Non-Conventional Armor Research (U)
Secret. November 1964

93. AD356495. Aircraft Armor Materials (U). Frankford Arsenal. Secret.
January 1965

94. AD-355586L - Research Test of Vulnerability of the CIE fuel in Unprotected Fuel Cells to Attack By Small Arms Projectiles (U)
Aberdeen Proving Ground. Conf. December 1964.

95. AD-354813. Composite Aircraft Armor Material Research and Development (U)
Goodyear Aerospace Corp. Conf. September 1964.

96. AD-354044L. Non-Conventional Armor Research (U).
Budd Co. Secret. July 1964

97. AD-354045L. Non-Conventional Armor Research (U)
Budd Co. Secret. June 1964

98. AD-354048L. Non-Conventional Armor Research (U)
Budd Co. Secret. May 1964

99. AD-354116L. Engineer Design Test of Aluminum Armor, 2219-T81 (Ballistic Evaluation) (U). Aberdeen Proving Ground. Conf. September 1964

100. AD-354270. Current Technology of Light Armor Materials for U. S. Army Aircraft (U). Army Materials Research Agency. Conf. May 1963

101. AD-353600L. Feasibility Study on Dual-Hardness Steel Armor for Caliber .50 AP Protection (U). Army Materials Research Agency. Conf. Sept 64.

102. AD-603558. Simulated Flight Test Investigation of the Effectiveness of a Lightweight Aircraft Fixed Fire-Extinguishing System.
Fenwal, Inc. Uncl. June 1964

103. AD-603746. Evaluation of Lightweight Fire Extinguishing System Under Simulated Flight Conditions. Fenwal, Inc. Uncl. April 1964

104. AD-444828L. Evaluation of Proprietary Intumescent Paint Coating.
NAEC, Philadelphia. Uncl. August 1964

105. AD-353323: Composite Aircraft Armor Materials Research and Development(U)
Goodyear Aerospace Corp. Conf. March 1964

106. AD-352628: Second Six Month Report on Lightweight Armor AMCMC Code 5026, 11.842.009(U). Army Munitions Command. Secret. August 1964

107. AD-351763L. Engineer Design Test of High-Hardness and High-Strength Alloy Steel Plate (Ballistic Evaluation) (U). Aberdeen Proving Ground.
Conf. July 1964

108. AD-351799: Aircraft Armor Materials(U). Frankford Arsenal. Secret.
July 1964

109. AD-351315. Ballistic Performance of Cast Aluminum Alloy Plates (U).
Frankford Arsenal. Conf. May 1964

110. AD-351323L. Engineer Design Test of Heat-Treatable, Weldable Aluminum Armor, 7039 Alloy (Ballistic Evaluation)(U). Aberdeen Proving Ground.
Conf. April 1964

111. AD-351362L. Engineer Design Test of Heat-Treatable, Weldable Alloys, M806-T6 and X7106-T6, Aluminum Armors (Ballistic Evaluation)(U).
Aberdeen Proving Ground. Conf. June 1964

112. AD-351596. Armor Materials for Defense Against .50 Caliber Ammunition(U) Army Materials Research Agency. Secret. June 1964

113. AD-351600L. Non-Conventional Armor Research (U). Budd Co. Secret. March 1964

114. AD-351608L. Non-Conventional Armor Research(U). Budd Co. Secret. Feb. 64

115. AD-601200. Study of Mechanisms of Armor Penetration Resistance. Philco. Uncl. January 1964

116. AD-351092L. Ballistic and Metallurgical Tests of Titanium Alloy Armor Plate(U). Naval Weapons Lab. Conf. June 1964

117. AD-350785. NLABS Report on Armor Materials Research (U) Army Natick Labs. Conf. April 1964

118. AD-351091L. Ballistic Evaluations of Composite Armor (U). Naval Research Lab. Secret. June 1964

119. AD-600387. Flammability and Smoke Characteristics of Aircraft Interior Materials. FAA. Uncl. January 1964

120. AD-440384L. Evaluation of Proprietary Intumescent Paint Coating. NAEC, Philadelphia. Uncl. May 1964

121. AD-349640. Aircraft Armor Materials (U). Frankford Arsenal. Conf. April 1964

122. AD-349735. Engineer Design Test - Ballistic Evaluation of Composite Armor Plate (U). Aberdeen Proving Ground. Conf. May 1964

123. AD-348945L. Aricraft Armor Program (U). Army Materials Research Agency. Secret. March 1964

124. AD-349057L. Non-Conventional Armor Research (U). Budd Co. Secret. January 1964

125. AD-349344L. Engineer Design Test of Stability of Aluminum Armor Alloys (Ballistic Evaluation)(U). Aberdeen Proving Ground. Conf. April 1964

126. AD-433566. Nitrogen Purge Equipment, Fire Protection and Safety Subsystem. Boeing Co. Uncl. March 1963.

127. AD-434931L. Non-Integral Fuel Tank Fire Tests. Coast Guard. Uncl. April 1964

128. AD-347855L. Fragment-Resistance of Martensitic Sheet Steel(U). Army Materials Research Agency. Conf. January 1964

129. AD-347443L. Metallurgical and Ballistic Study of Titanium for Armor (U) Army Materials Research Agency. Conf. December 1963

130. AD346930L. Assessments of the Lethality of Some Gun-Fired Projectiles Against a Typical Surveillance Helicopter and a Typical Ground-Attack Fighter Aircraft(U). Royal Aircraft Establishment, Gr. Brit. Conf. September 1963

131. AD-428984L. Non-Integral Fuel Tank Fire Tests. Coast Guard. Uncl. January 1964.

132. AD-346495L. Non-Conventional Armor Research Budd Co. Secret. November 1963

133. AD-346675L. Feasibility Study of Laminated Metallic Armor(U). Army Materials Research Agency. Conf. December 1963

134. AD-346825L. The Significance of Strength in Lightweight Steel Armor (U) Army Materials Research Agency. Conf. December 1963

135. AD-346122. Estimated Vulnerability and Armoring Considerations for Very Light Attack Aircraft (U). NADC, Johnsville. Conf. December 1963

136. AD-346238. Study of Mechanisms of Armor Penetration Resistance (U). Aeronutronic. Conf. October 1963

137. AD-345711L. Non-Conventional Armor Research(U) Budd Co. Secret. October 1963

138. AD-345737. UH-1 Aircrew Protection Kit Ballistic Test (U). Army, TRECOM. Conf. December 1963

139. AD-423336. Evaluation of Lightweight Fire Extinguishing System Under Simulated Flight Conditions. Fenwal, Inc. Uncl. October 1963

140. AD-343439L. Engineer Design Test of Titanium Armor (Ballistic Evaluation) (U). Army Test and Evaluation Command, Aberdeen. Conf. September 1963.

141. AD-417905. Evaluation of Lightweight Fire Extinguishing System Under Simulated Flight Conditions. Fenwal, Inc. Uncl. June 1963

142. AD-341006L. (Classified title) (Deals with armor research and design) Budd Co. Secret. July 1963

PART III

1. Report No. 19452. Vulnerability Testing of Aircraft Non-Metallic Fuel Tanks and Fire Suppression Material (U) Goodyear Tire and Rubber Co., Inc. Conf. December 1965

2. Report No. 19459. Self-Sealing Coating for Aircraft Inflammable Liquids in Lines and Tanks(U) Goodyear Tire and Rubber Co., Inc. Conf. 1965

APPENDIX D

ASSOCIATED REPORTS

ASSOCIATED REPORTS

1. Gunfire Tests of External Self-Sealing Materials for Fuel Tanks; TDMC:LF:bap 8960, Wright Patterson Air Force Base, Dayton, Ohio.

2. Gunfire Test of Self-Sealing Fuel Hoses; TDMC:LF:bap 8190/4; NAVAIRSYSCOM (AIR-52032).

3. Hose, Aircraft, Self-Sealing, Aromatic Fuel, MIL-H-7061, Evaluation of; Material Test Report No. 16615, dated 2 February 1966.

4. Aviation Fuel Safety; Project No. CA-37-64; Coordinating Research Council dated June 1964; Revised December 1964.

5. Improved Crash-Resistant Fuel Cell Material; USAAVLABS Technical Report 67-6; dated April 1967.

6. Aircraft Fuel Systems Design Study; USAAVLABS Technical Report 67-33; dated June 1967.

7. Aircraft Fuel Tank Design Criteria USAAVLABS Technical Report 66-24; dated March 1966.

APPENDIX E

LIST OF MANUFACTURERS AND MATERIALS

Table E-I
INDUSTRY SURVEY

Questionnaires To	Contacted by Telephone	Questionnaire Answered	Visits Made	Information
Falcon Research and Development, Denver, Colorado	no	yes	no	none
North American Aviation, Columbus, Ohio	yes	yes	no	U.S. 173 modified used on T28 U.S. 180 used on OV-10A
Grumman Aircraft, Bethpage, Long Island, New York	yes	yes	no	none
McDonnell Aircraft, St. Louis, Missouri	no	yes	no	Good response on F-4A, F-101, F3H,F2H Tanks
Lockheed, Marietta, Georgia	no	yes	no	none
Lockheed, Burbank, California	yes	Letter Only	yes	Currently investigating both self-sealing tanks and foam
Douglas Aircraft, Los Angeles, California	yes	yes	no	A4 uses Firestone 1146 compositions
Republic Aviation, Farmingdale, New York	yes	no	no	None;self-seal installation under development
Boeing, Wichita, Kansas	no	yes	no	none
Northrop-Norair Hawthorne, California	no	yes	no	none
General Dynamics, Ft. Worth, Texas	yes	no	no	No self-seal background
Convair, San Diego, California	no	no	no	none

Questionnaires To	Contacted by Telephone	Questionnaire Answered	Visits Made	Information
North American, Los Angeles, Calif.	no	Letter Only	no	U.S. 170 used in F-86
Bell Helicopter, Ft. Worth, Texas	no	no	no	none
Sikorsky Aircraft, Stratford, Conn.	no	yes	no	Goodyear FTL13 used on S-61, S-64 Type Alc and FTL11-3 on S-65
Boeing Co.(Vertol) Morton, Pa.	no	yes	no	Use U.S. 173
Kaman Aircraft Bloomfield, Conn.	no	yes	no	Goodyear FTL-94 used on HH43F
Hughes Aircraft, Culver City, Calif.	no	no	no	none
Ballistics Research Lab, Aberdeen, Maryland	yes	yes	yes	Background on various materials development and incendiary firings
U.S. Naval Air Station, San Diego, California	no	no	no	none
U.S. Naval Weapons Lab, Dahlgrem, Va.	yes	yes	no	Questionnaire forwarded to NAVAIR (Code Air-530318) No recent testing results
U.S. Army Transportation Research Command, Ft. Eustis, Virginia	yes	yes	no	No testing being done at Ft. Eustis
Goodyear, Akron, Ohio	yes	yes	no	Detail drawings on 12 compositions and one exterior coating FLC-1

Questionnaires To	Contacted by Telephone	Questionnaire Answered	Visits Made	Information
Goodrich, Akron, Ohio	no	yes	no	Do not make S/S materials anymore
Goodyear, Arizona	yes	yes	yes	Has new products ARM 024 and ARM 1800
Firestone, Akron, Ohio	yes	yes	yes	Trip made to Los Angeles facility
Uniroyal, Indiana	yes	yes	no	Report FC-951 submitted
Conolite, Carpenterville, Illinois	yes	yes	no	Complete catalog of 25 compositions manufactured including technical data for all
Swedlow, Garden Grove, California	yes	no	no	none
Air Logistics, Pasadena, Calif.	yes	yes	no	New defense composite plus numerous compositions for analysis
M.C. Gill Corp., El Monte, Calif.	yes	yes	no	New compositions gladly submitted for test; 1068 and 1075
3M Company, St. Paul, Minn.	yes	yes	no	Very good description of HC-1101
Goodrich Hose Plant, Akron, Ohio	yes	yes	no	Good response on self-sealing hose, but hose not tested here
Eglin Air Force Base, Florida	no	no	no	none

Questionnaires To	Contacted by Telephone	Questionnaire Answered	Visits Made	Information
Boeing Airplane, Seattle, Washington	yes	no	no	Boeing has performed some research on ram pressure effects in fuel tanks
Boeing Airplane, Renton, Washington	yes	Letter Only	no	No use of S/S

TABLE E-II
CANDIDATE BACKING BOARD MATERIALS

COMPOSITION	WEIGHT (Lbs/Ft^2)	THICKNESS (Inch)	PROTECTION LEVEL	USED ON	COMPANY
ARM018	0.35	0.070	Cal 50	None	Goodyear Aerospace Litchfield Park, Arizona
ARM1800	Not Avail.	Not Avail.	Cal 50	None	Goodyear Aerospace Litchfield Park, Arizona
B26FG1W	0.21	0.026	Cal 50	L-19, S-61	Conolite Inc. Carpentersville, Illinois
B33FG1W	0.30	0.033	Cal 50	A-7, S-65	Conolite Inc. Carpentersville, Illinois
B60RK2W	0.49	0.060	Cal 50	Unknown	Conolite Inc. Carpentersville, Illinois
Gillfab 1068 .025 Thick	0.27	0.025	Cal 30	Unknown	M. C. Gill Corp. El Monte, Calif.
Gillfab 1068 .030 Thick	0.32	0.030	Cal 50	Unknown	M. C. Gill Corp. El Monte, Calif.
Gillfab 1075 .025 Thick	0.27	0.025	Cal 30	Unknown	M. C. Gill Corp. El Monte, Calif.
Gillfab 1075 .030 Thick	.032	0.030	Cal 50	Unknown	M. C. Gill Corp. El Monte, Calif.
700SI-EN2-23	0.25	0.023	Cal 30	None	Air Logistics Pasadena, Calif.
700SI-EN2-41	0.42	0.041	Cal 50	None	Air Logistics Pasadena, Calif.
700SI-EU1-61	0.66	0.061	Cal 50	None	Air Logistics Pasadena, Calif.
B-2	0.41	0.080	Cal 50	A4	Firestone Coated Fabrics Co., Akron, Ohio
F1-41	0.41	0.080	Cal 50	A4	Firestone Coated Fabrics Co., Akron, Ohio

TABLE E-III
CANDIDATE SELF-SEALING MATERIALS

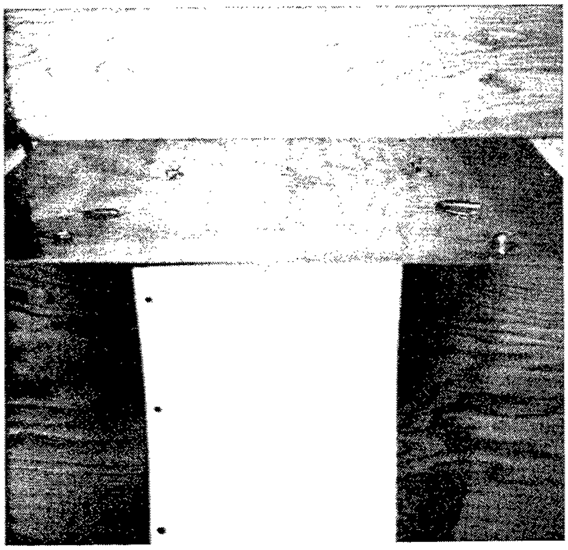
COMPOSITION	WEIGHT (Lbs/Ft^2)	THICKNESS (Inch)	PROTECTION LEVEL	USED ON	COMPANY
US173	1.15	0.217	Cal 50	CH-47, A-6 CH-46	UniRoyal Inc. Mishawaka, Indiana
US182	0.86	0.173	Cal 50	A-7	UniRoyal Inc. Mishawaka, Indiana
US179	0.64	0.122	Cal 30	UH-1D CH-47	UniRoyal Inc. Mishawaka, Indiana
US180	0.49	0.102	Cal 30	AH-1G OV-10A AT-37	UniRoyal Inc. Mishawaka, Indiana
US181	0.77	0.147	Cal 30	T-28	UniRoyal Inc. Mishawaka, Indiana
FTL 11-3	1.20	0.247	Cal 50	S-65, B-47 F84F, F3H F-101	Goodyear Tire & Rubber Co., Akron, Ohio
DX325 (FTL-17)	0.855	0.170	Cal 50	None	Goodyear Tire & Rubber Co., Akron Ohio
FTL-13	0.543	0.100	Cal 30	S-61, S-64 HH-3	Goodyear Tire & Rubber Co., Akron, Ohio
ARM-024	1.00	0.250	Cal 50	None	Goodyear Aerospace Litchfield Park, Arizona
1146	1.31	0.244	Cal 50	A-4, TA-4	Firestone Coated Fabrics Co., Akron, Ohio
1451-1	0.57	0.118	Cal 30	L-19	Firestone Coated Fabrics Co., Akron, Ohio
E1316-3	1.01	0.209	Cal 30	Air boats	Firestone Coated Fabrics Co., Akron, Ohio
FLC-1	2.0	0.375	--	LOH, SH-3A P2V	Goodyear Tire & Rubber Co., Akron, Ohio
HC-1101	1.77	0.375	--	None	3M Company St. Paul, Minn.
114509-102	--	--	--	C-123	Air Logistics, Pasadena, Calif.

TABLE E-III (Continued)

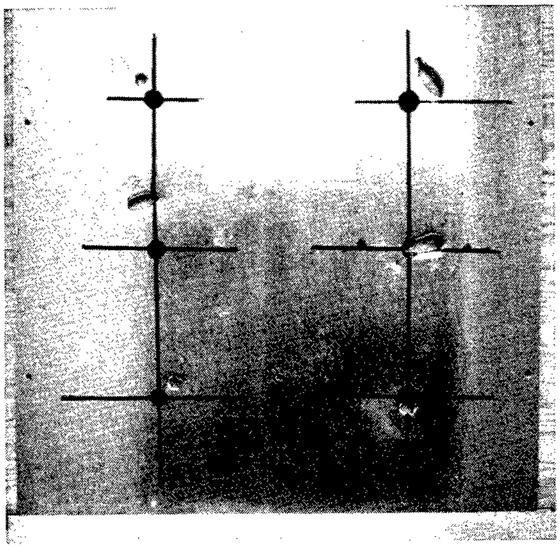
COMPOSITION	WEIGHT (Lbs/Ft^2)	THICKNESS (Inch)	PROTECTION LEVEL	USED ON	COMPANY
114509-217	--	--	--	None	Air Logistics, Pasadena, Calif.
114509-304	--	--	Cal 50	None	Air Logistics, Pasadena, Calif.

APPENDIX F

PHOTOGRAPHS - DRY SKIN FIRING

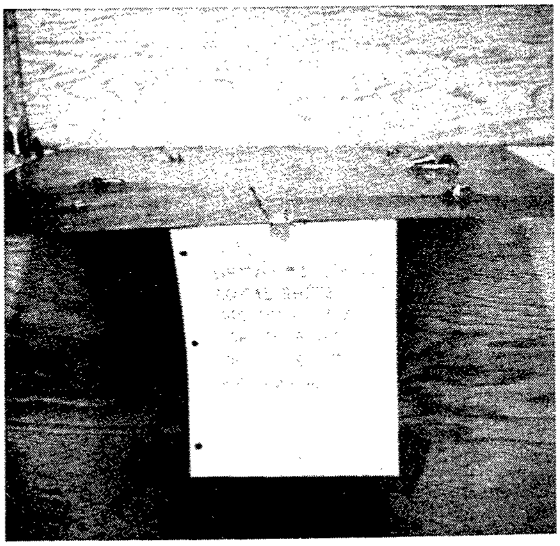


(a)

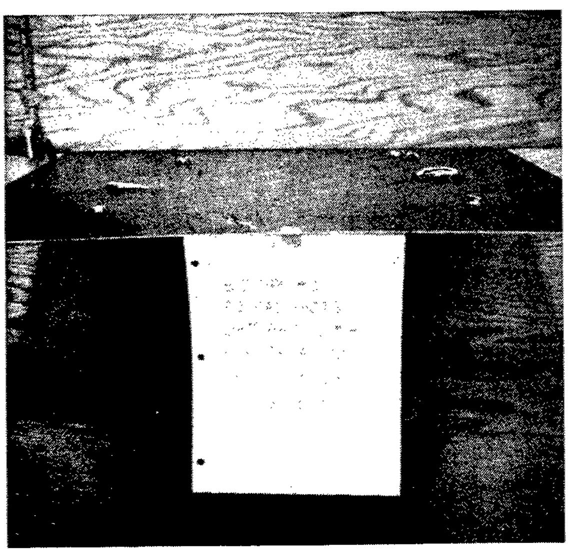


(b)

(c)



(d)



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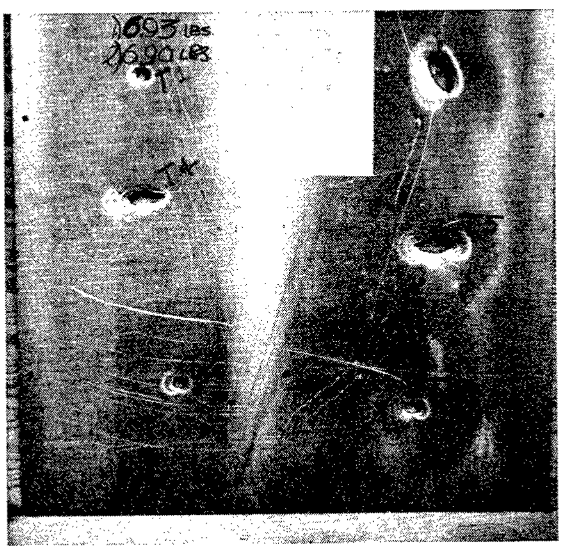


(f)

Figure F-1 CALIBER .50 SHOTS, 6061-T6 ALUMINUM

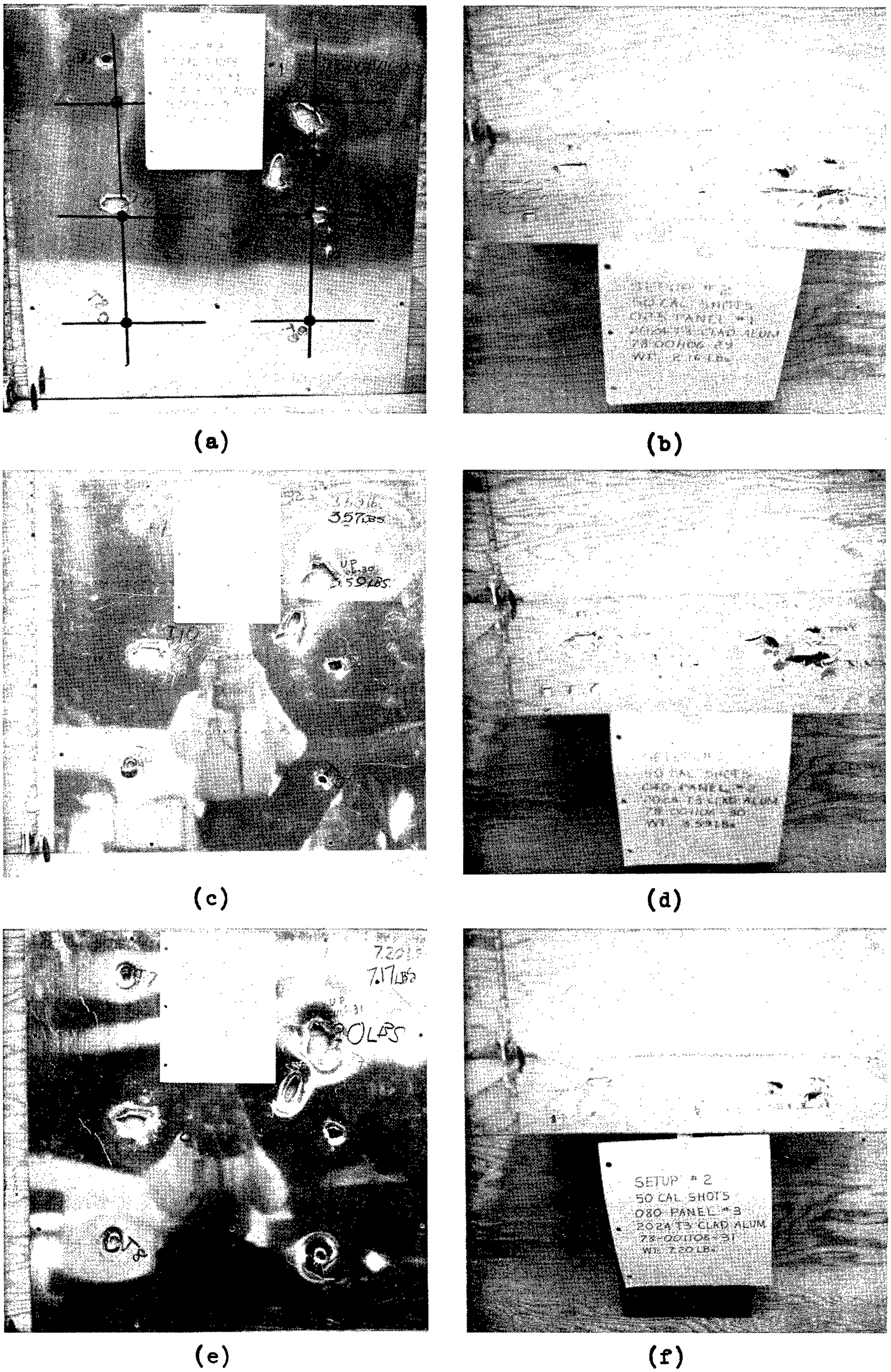
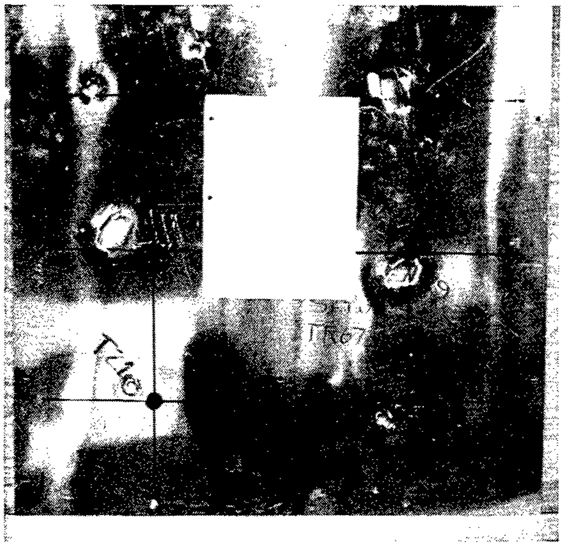
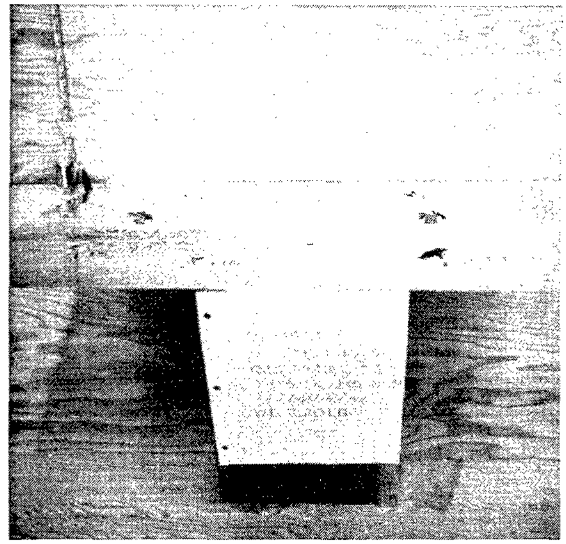
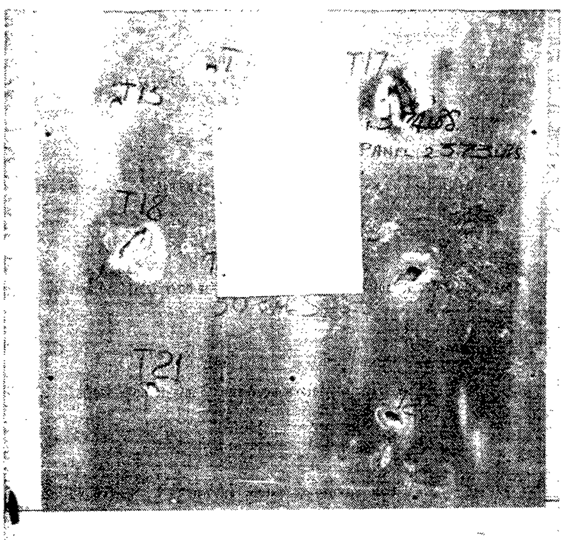


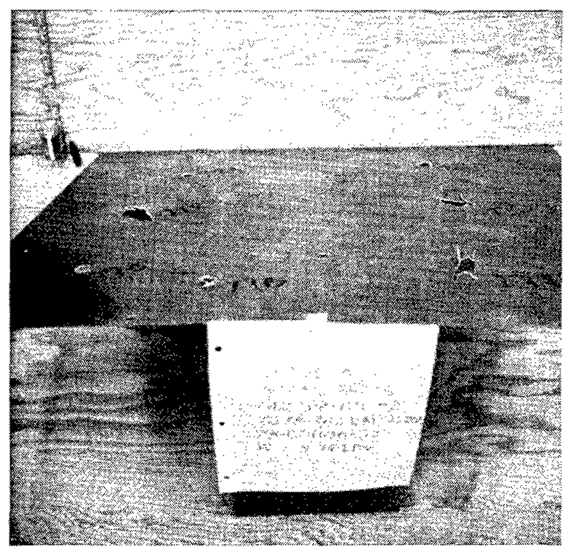
Figure F-2 Caliber .50 Shots, 2024-T3 Aluminum



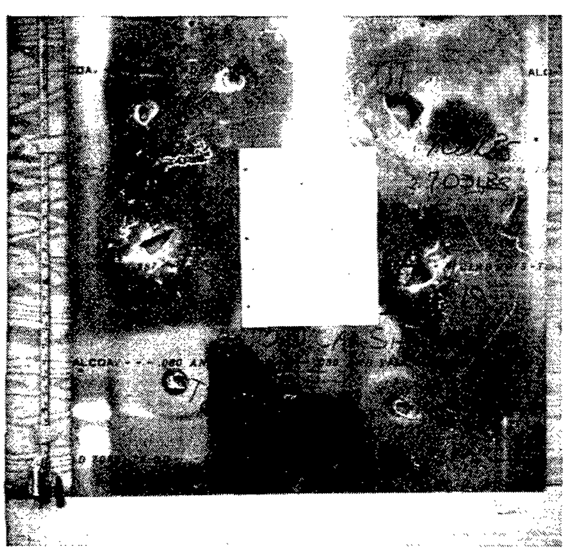


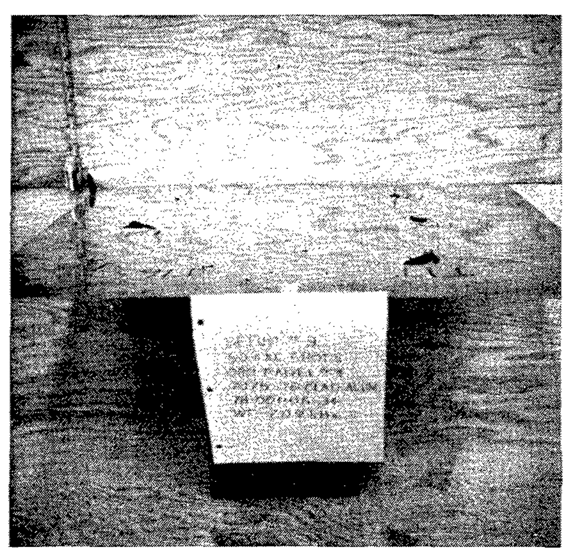
(a) (b)





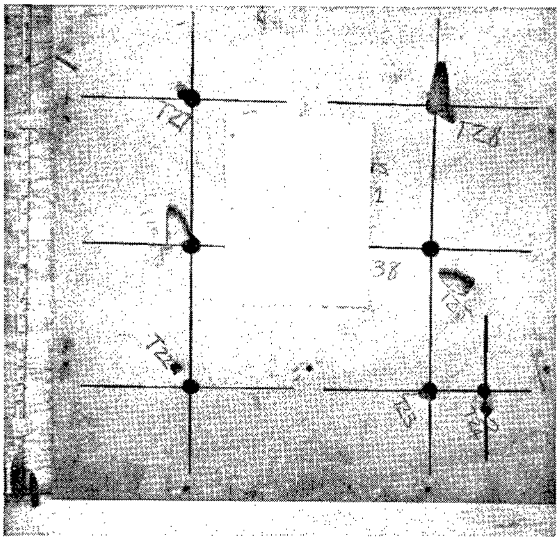
(c) (d)





(e) (f)

Figure F-3 Caliber .50 Shots, 7075-T6 Clad Aluminum



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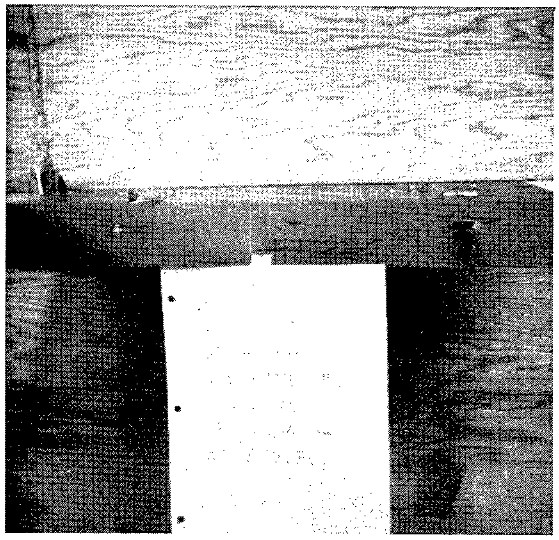
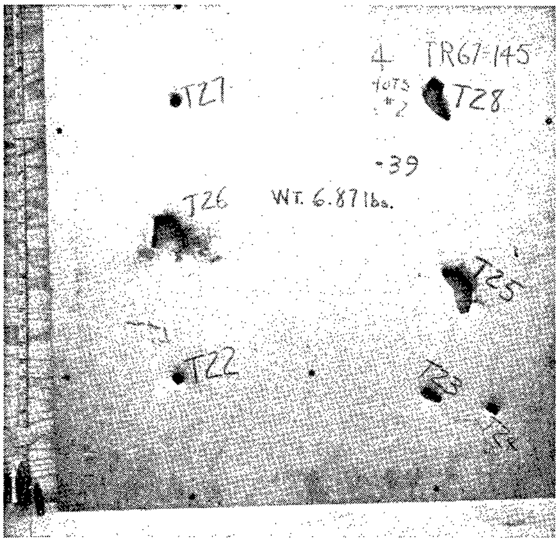


(b)



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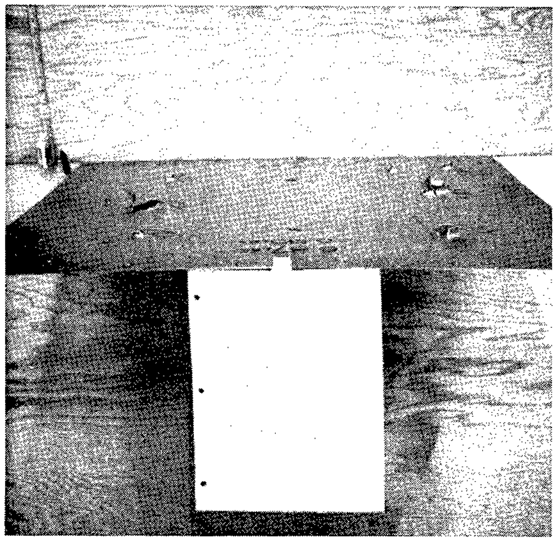

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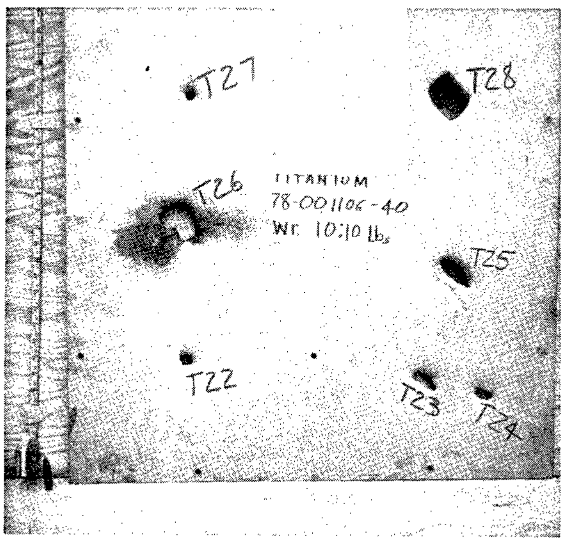
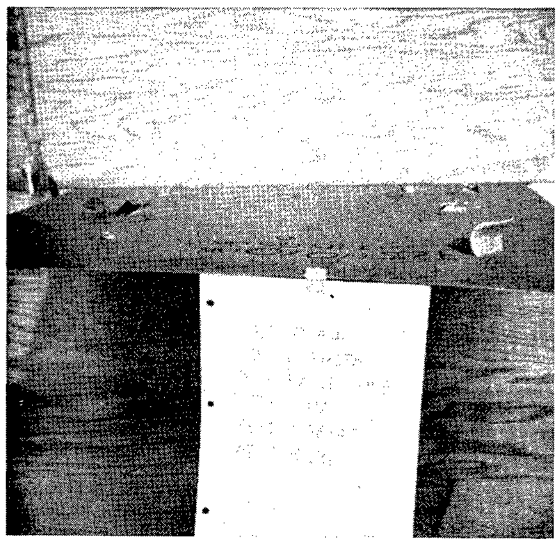
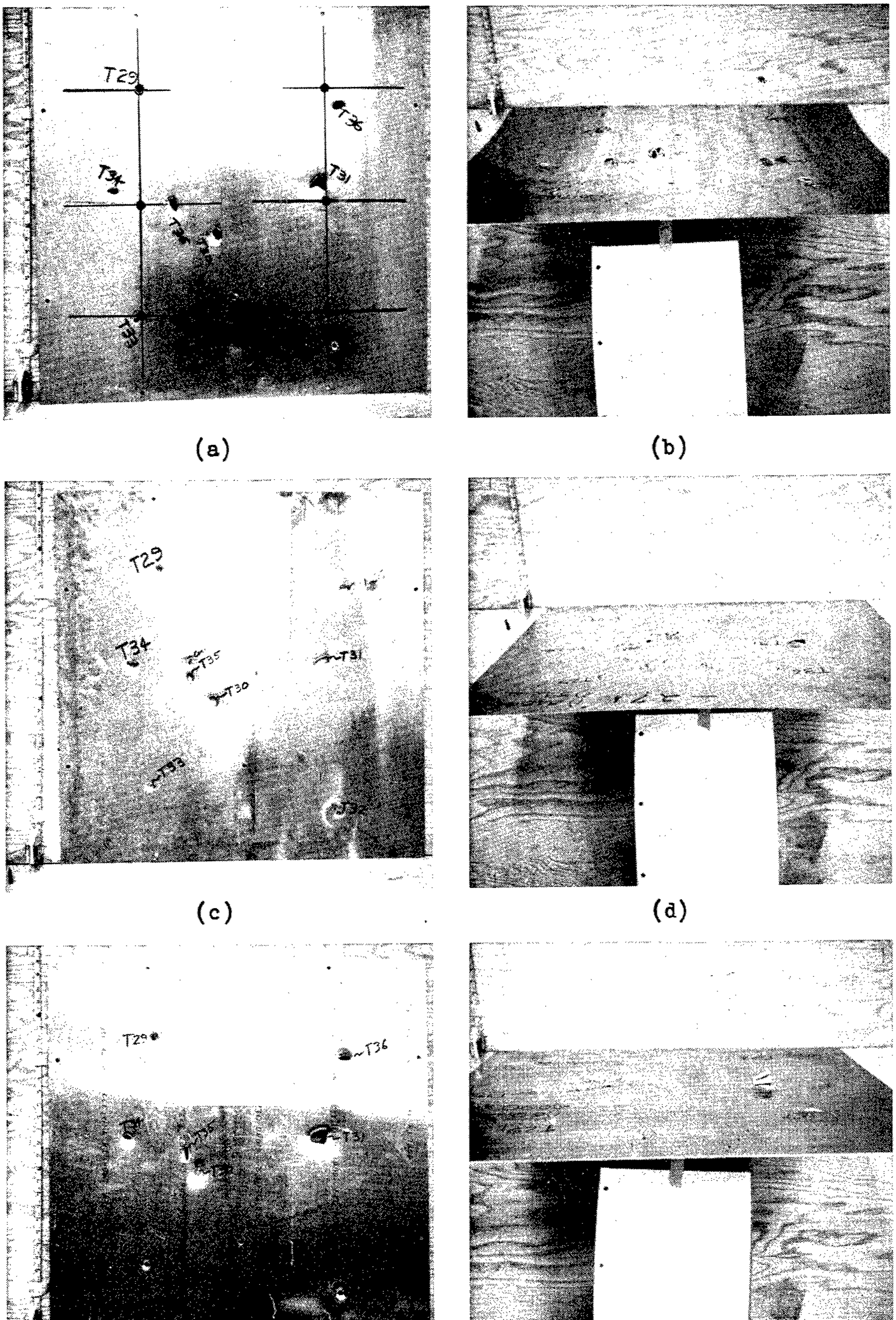


(e)



(f)

Figure F-4 Caliber .50 Shots, Titanium

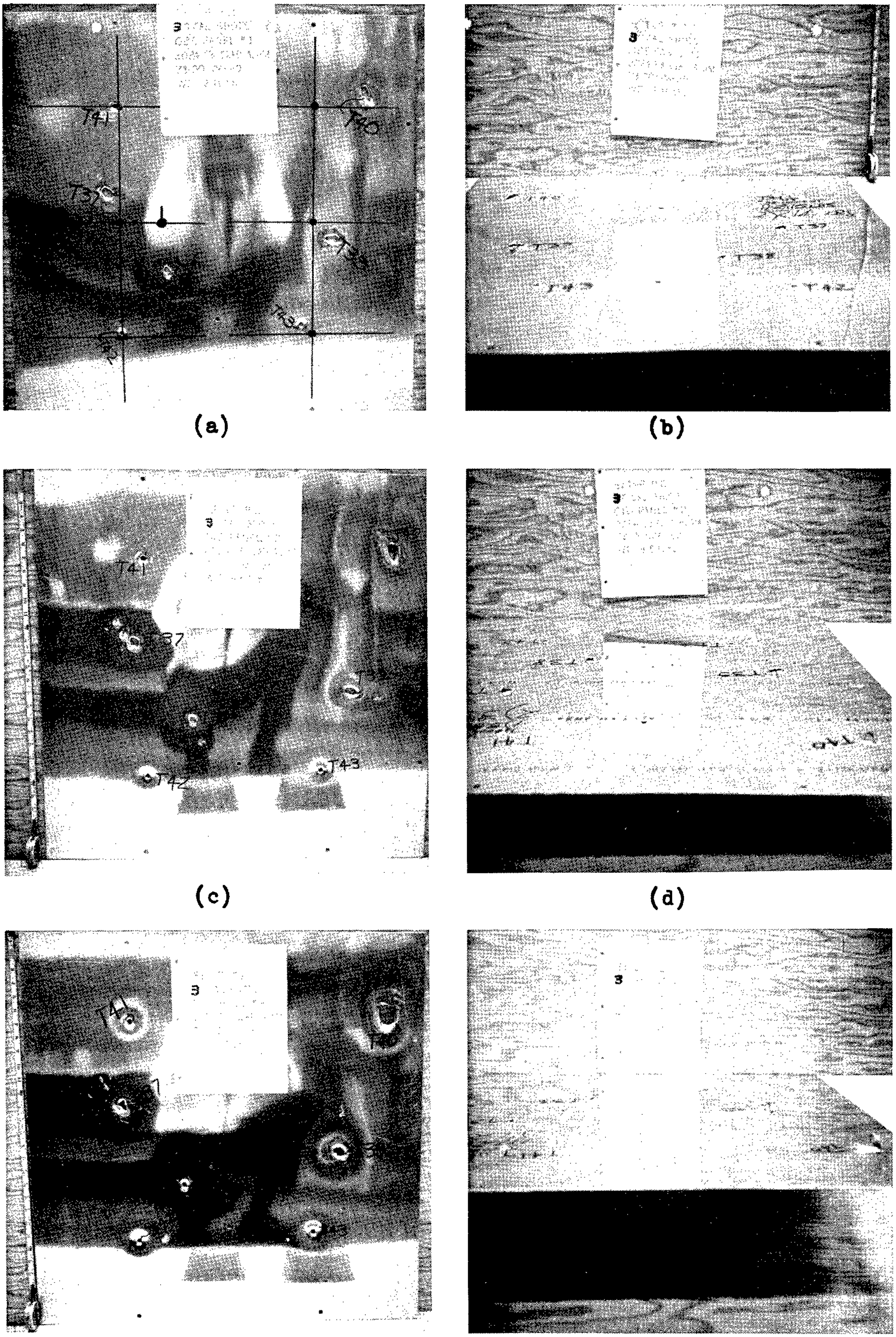


(a) (b)

(c) (d)

(e) (f)

Figure F-5 Caliber .30 Shots, 6061-T6 Aluminum

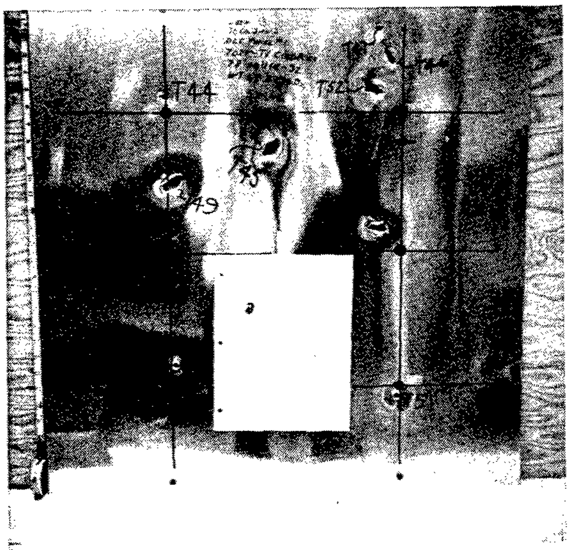


(a) (b)

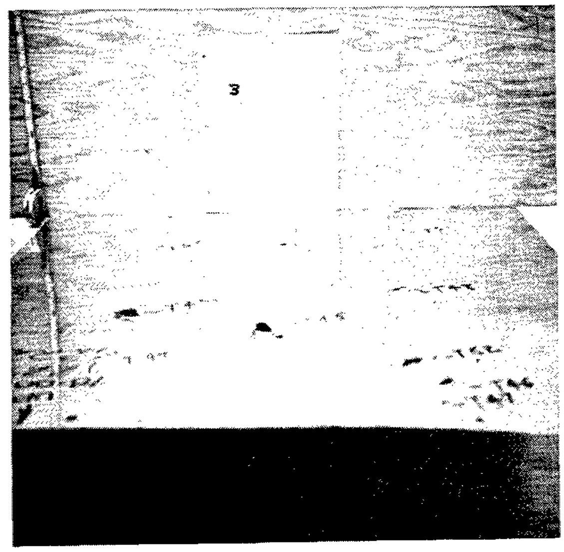
(c) (d)

(e) (f)

Figure F-6 Caliber .30 Shots, 2024-T3 Aluminum



(a)



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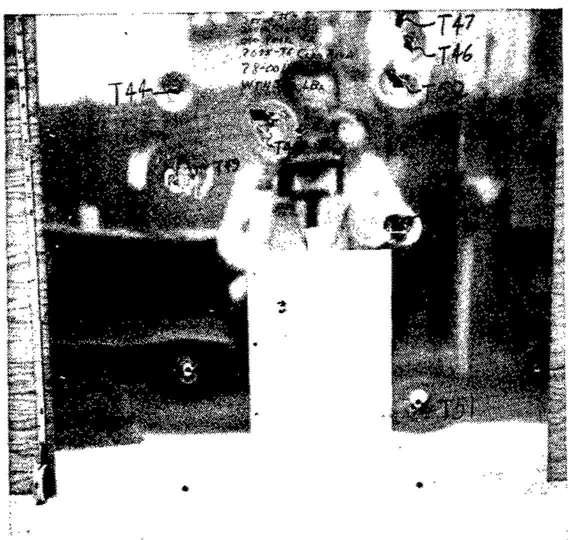

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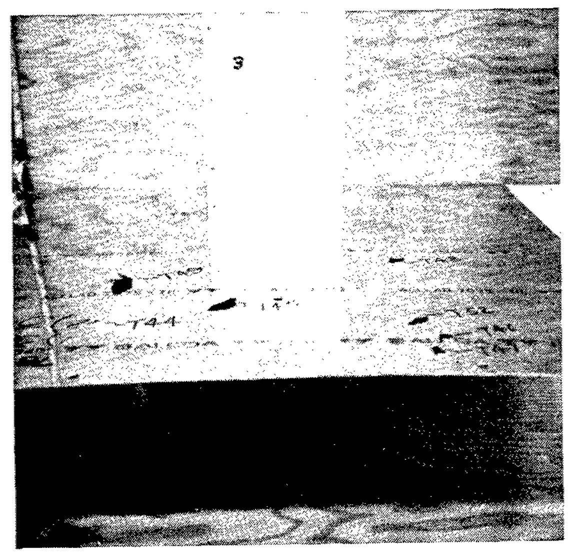

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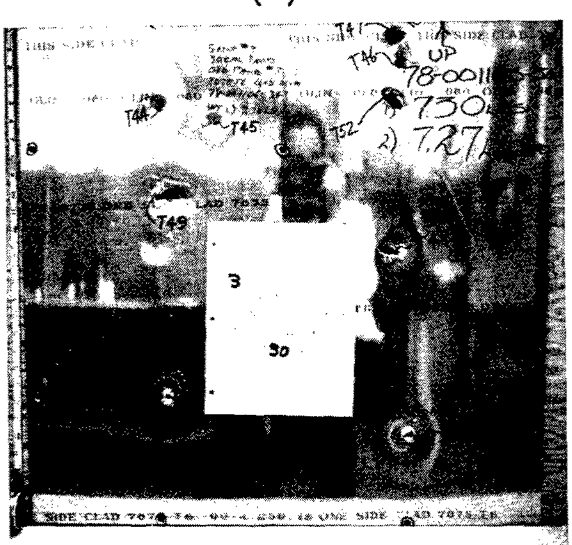

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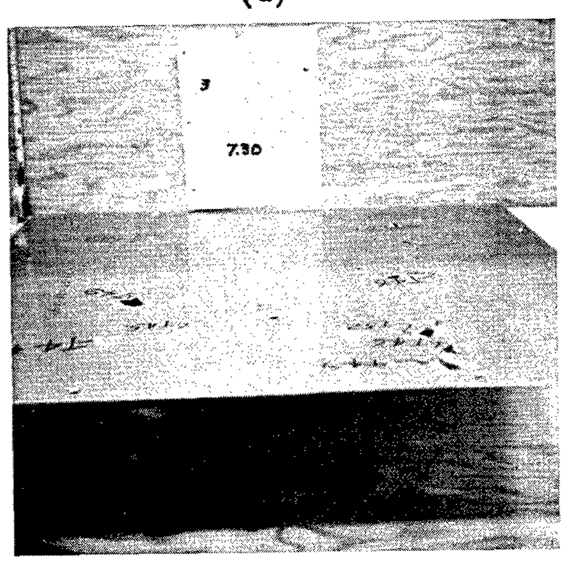
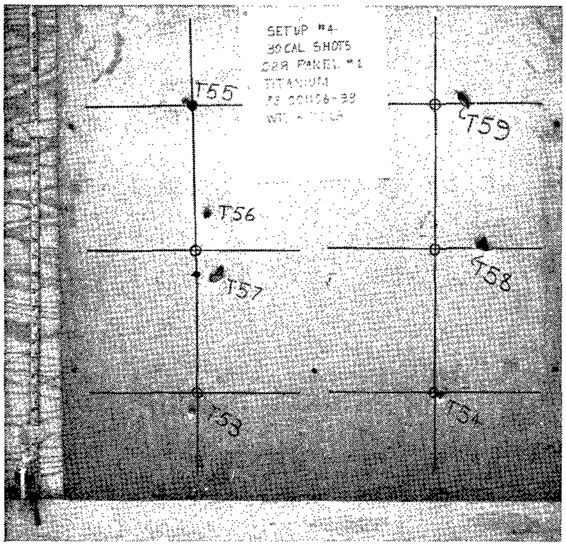
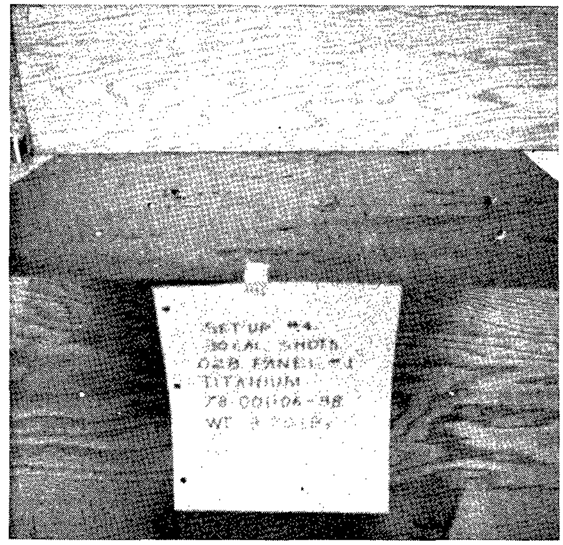


(f)

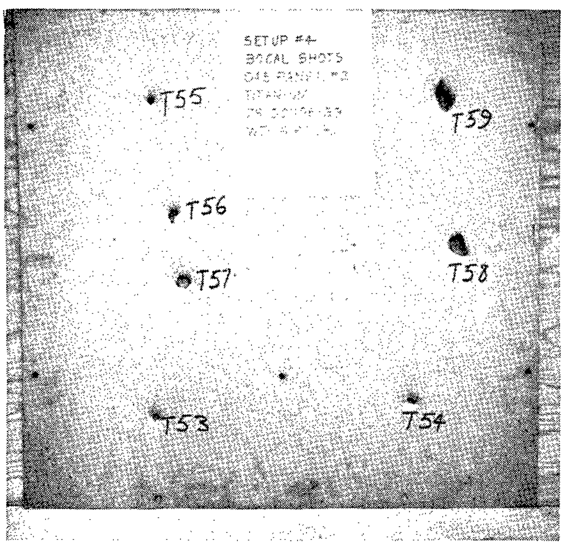
Figure F-7 Caliber .30 Shots, 7075-T6 Clad Aluminum



(a)



(b)



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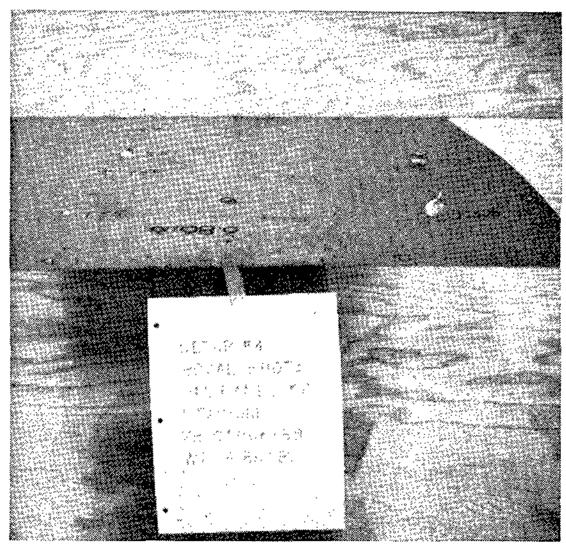

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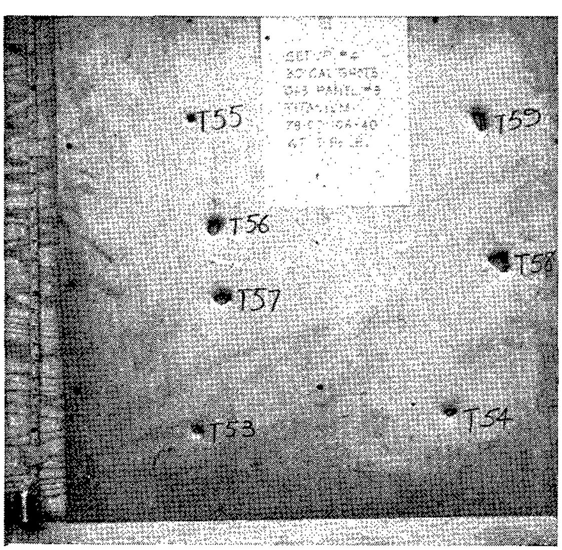

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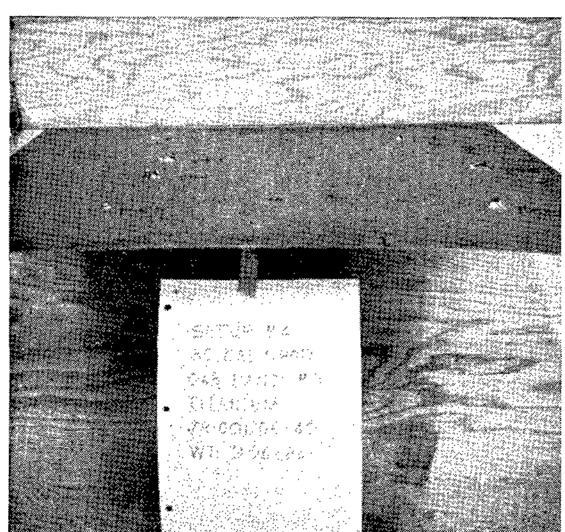


(f)

Figure F-8 Caliber .30 Shots, Titanium

APPENDIX G

DATA SHEETS: DRY SKIN FIRING

REF: FIGURE F-1

TABLE G-I

SKIN PETALING TEST-Cal.50

ALLOY: 6061-T6 ALLOY

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.025) PETAL HEIGHT (IN.)	SKIN #1 (.025) DESCRIPTION	SKIN #2 (.040) PETAL HEIGHT (IN.)	SKIN #2 (.040) DESCRIPTION	SKIN #3 (.080) PETAL HEIGHT (IN.)	SKIN #3 (.080) DESCRIPTION
--	S.T	100	2899	--	Practice Round	--	--	--	--
T1	S.T.	100	2920	.24	O.H., S.T.	.31	O.H.	.30	U.H.
T2	S.T.	85	2353	.29	O.H., S.T.	.29	O.H.	.44	P.S.
T3	S.T.	50	1434	.33	S.T.	.32	P.T.E.	.45	P.T.E.
T4	TUM.	100	2878	.24	F.T.E., Cored	.69	P.S.,F.T.E.,Cored	.42	P.S.,F.T.E.,Cored
T5	TUM.	85	2312	.41	F.T.E., Cored	.93	F.T.E., P.S.,Cored	.61	F.T.E.,P.S.,Cored
--	TUM.	50	1399	--	No Information		Obtained	--	--
--	TUM.	50	1399	--	No Information		Obtained	--	--
T6	TUM.	50	1413	.38	F.T.E., Cored	.76	F.T.E., Cored	.51	F.T.E.,P.S.,Cored

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-2

TABLE G-II

SKIN PETALING TEST-Cal.50

ALLOY: 2024-T3 CLAD

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.025)		SKIN #2 (.040)		SKIN #3 (.080)	
				PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION
T7	S.T.	100	2941	.19	O.H., S.T.	.24	P.R.,P.S.,S.T.	.34	P.R.,P.S.,U.H.,S.T.
T8	S.T.	85	2395	.26	P.R.,O.H.,S.T.	.30	P.R., S.T.	.47	P.R.,P.S., O.H.,P.T.E.
T9	S.T.	50	1471	.27	P.R.,O.H.,S.T.	.32	P.R.,O.H.,S.T.	.40	P.S.,P.T.E.
T10	TUM.	100	2857	.33	P.R.,O.H.,F.T.E., Cored	.60	O.H.,P.S.,F.T.E. Cored	.57	P.R., P.S., O.H., F.T.E., CORED
T11	TUM.	85	2326	.40	P.R.,O.H.,P.T.E.	.43	P.R.,O.H.,P.S., P.T.E.	.57	P.R.,P.S.,P.T.E., O.H.
T12	TUM.	50	1351	.41	P.R.,O.H.,F.T.E.	.74	O.H.,P.S.,F.T.E.	.54	P.S.,O.H.,F.T.E.
T13 (Repeat T11)	TUM.	85	2260	.49	P.R.,O.H.,F.T.E.	1.01	P.R.,O.H.,F.T.E.	.86	P.R.,P.S.,O.H., F.T.E.

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-3

TABLE G-III

SKIN PETALING TEST -Cal.50

ALLOY: 7075-T6 CLAD

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.025)		SKIN #2 (.040)		SKIN #3 (.080)	
				PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION
T15	S.T.	100	--	.37	P.R.,O.H.,P.T.E., Cored	.25	O.H.,P.T.E.,Cored	.39	O.H.,P.S.,P.T.E., Cored
T16	S.T.	100	2878	.23	P.R.,S.T.,Cored	.32	U.H.,S.T.,P.R., Cored	.37	U.H.,P.S.,S.T., Cored
T17	TUM.	50	1408	.62	P.R.,O.H.,F.T.E., Cored	.65	O.H.,F.T.E.,P.R., Cored	.74	O.H.,P.S.,F.T.E., Cored
T18	TUM.	100	--	.35	O.H.,F.T.E.,Cored	.41	P.S.,F.T.E.,Cored	.37	O.H.,P.S.,F.T.E., Cored
T19	TUM.	85	2381	.41	P.R.,O.H.,F.T.E., Cored	.44	P.S.,O.H.,F.T.E., P.R., Cored	.13	O.H.,P.S.,F.T.E., Cored
T20	S.T.	50	1460	.44	P.R.,O.H.,P.T.E., Cored	.15	P.T.E., Cored	.82	O.H.,P.S.,P.T.E., Cored
T21	S.T.	85	2381	.27	P.R.,S.T.,Cored	.63	O.H.,S.T.,Cored	.39	U.H.,P.S.,P.T.E., Cored

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-4

TABLE G-IV

SKIN PETALING TEST -Cal.50

ALLOY: AMS4901 TITANIUM

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.028)		SKIN #2 (.045)		SKIN #3 (.063)	
				PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION
T22	S.T.	85	2299	.30	O.H.,S.T.,P.D.	.47	U.H.,S.T.,P.D.	.76	U.H.,P.S.,S.T.,P.D.
T23	S.T.	50	1429	.59	P.R.,P.D.,O.H., P.T.E., Cored	.61	O.H.,P.T.E.,P.D., Cored	.74	O.H.,P.D.,P.T.E., Cored
T24	S.T.	50	1399	.49	P.R.,O.H.,P.T.E.	.45	P.R.,O.H.,P.T.E.	.97	P.R.,O.H.,P.T.E.
T25	TUM.	85	--	.59	P.R.,O.H.,F.T.E., Cored	.72	P.R.,O.H.,P.S., F.T.E., Cored	.86	O.H.,P.S.,F.T.E. Cored
T26	TUM.	100	2837	.63	P.R.,O.H.,P.D., F.T.E.	1.33	P.R.,F.T.E.,O.H., P.S.,P.D., Burned Metal	1.1	P.R.,F.T.E.,O.H., P.D.,P.S., Burned Metal
T27	S.T.	100	2920	.30	U.H.,S.T.,P.D.	.42	U.H.,P.S.,P.D.,S.T	.51	U.H.,S.T.,P.D.,P.S.
T28	TUM.	50	1418	.93	P.R.,O.H.,F.T.E.	.88	P.R.,O.H.,F.T.E.	1.83	P.S., P.R.,O.H.,F.T.E,

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-5

TABLE G-V

SKIN PETALING TEST -Cal.30

ALLOY: 6061-T6

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.025)		SKIN #2 (.040)		SKIN #3 (.080)	
				PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION
T29	S.T.	100	2703	.24	S.T.,O.H.	.27	S.T.,O.H.	.31	S.T., Cored
T30	TUM.	50	--	.29	P.R.,O.H.,P.T.E., Cored	.35	O.H.,P.T.E,P.R.	.26	No Exit, Dented Skin F.T.E.
T31	TUM.	50	--	.35	P.R.,O.H.,F.T.E., Cored	.44	O.H.,P.S.,F.T.E., Cored	1.28	O.H., P.S., P.D.,F.T.E.
T32	S.T.	50	--	.21	S.T.,P.R.	.29	S.T.,U.H.	.36	S.T.,U.H.,Cored
T33	S.T.	70	--	.26	P.D.,S.T.	.26	P.D.,S.T.,U.H.	.27	P.R.,S.T.,U.H., Cored
T34	TUM.	100	2597	.24	P.T.E.,O.H.,P.R.	.23	P.T.E.,O.H.,Cored	.25	P.T.E., Cored
T35	TUM.	100	2614	.29	F.T.E.,O.H.,Cored	.26	O.H., Cored F.T.E.,P.S.,	.26	F.T.E.,P.S.,Cored
T36	TUM.	70	1932	.23	P.T.E.,P.R.,O.H., Cored	.27	F.T.E.,O.H.,P.S., Cored	.28	F.T.E.,P.S.,Cored

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-6

TABLE G-VI

SKIN PETALING TEST-Cal.30

ALLOY: 2024-T3 CLAD

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.025) PETAL HEIGHT (IN.)	SKIN #1 (.025) DESCRIPTION	SKIN #2 (.040) PETAL HEIGHT (IN.)	SKIN #2 (.040) DESCRIPTION	SKIN #3 (.080) PETAL HEIGHT (IN.)	SKIN #3 (.080) DESCRIPTION
T37	TUM.	100	2614	.29	P.T.E.,O.H.,Cored	.30	P.R., P.T.E.,O.H.,P.S.	.14	P.T.E.,O.H.,P.S., Cored
T38	TUM.	100	2564	.24	P.T.E,P.R.,O.H., Cored	.30	P.S.,P.R.,P.T.E., O.H.	.28	S.T.,U.H.,P.S., Cored
T39	TUM.	70	--	.26	P.T.E.,O.H.,P.R., Cored	.32	P.T.E,P.R.,O.H., P.S.	.47	P.T.E.,O.H.,P.R., P.S., Cored
T40	TUM.	50	--	.27	F.T.E.,O.H.,Cored	.52	F.T.E,O.H.,P.S.	1.33	F.T.E.,O.H.,P.R., P.S.
T41	S.T.	100	2721	.18	S.T.,O.H.,P.R.	.21	S.T.,O.H.,P.R.	.23	S.T.,U.H.,P.S., Cored
T42	S.T.	70	1951	.16	S.T.,U.H.,P.R.	.23	S.T.,U.H.,P.R.	.23	S.T.,U.H.,P.D., Cored
T43	S.T.	50	1384	.23	S.T.,U.H.,P.R.	.27	S.T.,U.H.,P.R.	.36	S.T.,U.H.,P.D., Cored

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-7

TABLE G-VII

SKIN PETALING TEST -Cal.30

ALLOY: 7075-T6 CLAD

ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.025)		SKIN #2 (.040)		SKIN #3 (.080)	
				PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION
T44	S.T.	100	2685	.19	S.T.,P.R.,Cored	.23	S.T.,U.H.,Cored	.18	S.T.,U.H.,Cored
T45	TUM.	50	--	.76	P.T.E.,O.H.,Cored	.13	P.T.E.,O.H.,Cored	--	No Exit
T46	TUM.	50	--	.30	P.T.E.,U.H.,P.R.	.38	P.T.E.,P.R.,Cored	.39	P.T.E.,O.H.,Cored
T47	TUM.	50	--	.26	Cored S.T.,U.H.,P.R.,	.25	P.T.E.,O.H.,Cored	.26	P.T.E.
T48	TUM.	70	--	.30	P.T.E.,O.H.,P.R., Cored	.42	P.T.E,O.H.,P.R., P.S., Cored	.06	P.T.E.,O.H.,P.S., Cored
T49	TUM.	100	--	.32	F.T.E.,O.H.,P.R., Cored	.42	F.T.E.,O.H.,P.R., P.S., Cored	.39	F.T.E,O.H.,P.S., Cored
T50	S.T.	70	1923	.21	S.T.,U.H.,P.R.	.26	S.T.,U.H.,P.R., Cored	.28	S.T.,U.H.,Cored
T51	S.T.	50	1384	.21	S.T.,U.H.,P.R.	.27	S.T.,U.H.,P.R., Cored	.25	S.T.,U.H.,Cored
T52	TUM.	50	1356	.46	F.T.E,,O.H.,P.R., Cored	.48	F.T.E.,O.H.,P.S., Cored	.58	F.T.E.,O.H.,P.S., Cored

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

REF: FIGURE F-8

TABLE G-VIII

SKIN PETALING TEST -Cal.30

ALLOY: AMS4901 TITANIUM

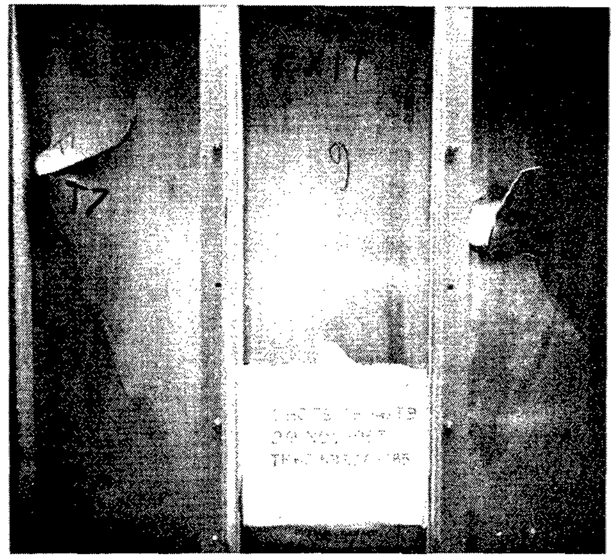
ROUND	MODE	POWDER CHARGE %	VELOCITY FT/S	SKIN #1 (.028)		SKIN #2 (.045)		SKIN #3 (.063)	
				PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION	PETAL HEIGHT (IN.)	DESCRIPTION
T53	S.T.	70	1914	.21	S.T.,U.H.,Cored	.22	S.T.,U.H.,Cored	.28	S.T.,P.D.,Cored
T54	S.T.	50	1370	.22	S.T.,U.H.,Cored	.30	S.T.,U.H.,Cored	.49	S.T.,U.H.,P.D.
T55	S.T.	100	--	.20	S.T.,U.H.,P.D., Cored	.23	S.T.,U.H.,Cored	.23	S.T.,U.H.,P.D., Cored
T56	TUM.	100	2484	.29	P.D.,Cored	.39	P.T.E.,O.H.,Cored	.57	P.T.E.,P.D.,Cored
T57	TUM.	100	2424	.30	P.T.E.,P.R.,P.D., Cored	.52	P.T.E.,O.H.,P.R., P.S., Cored	.70	F.T.E.,O.H.,P.S. P.D., Cored
T58	TUM.	70	1896	.39	F.T.E.,O.H.,P.D., P.R., Cored	.78	F.T.E.,O.H.,P.R.	.45	F.T.E,O.H.,P.D., Cored
T59	TUM.	50	1220	.41	F.T.E.,U.H.,P.R., Cored	.83	F.T.E.,O.H.,Cored	.70	F.T.E.,U.H.,P.D.

1. P.R. = Petal Rolled
2. F.T.E. = Full Tumbled Entry (3/4 to Full)
3. P.T.E. = Partial Tumbled Entry (Under 3/4)
4. O.H. = Skin Hole Larger than Projectile
5. P.D. = Projectile started to lose Jacket
6. CORED = Visual Inspection of Hole in Skin
7. S.T. = Straight Thru Shot - 90° Angle to Skin
8. U.H. = Undersize Hole - Hole Diameter less than fired projectile diameter.
9. P.S. = Entrance Surface of Skin Pitted and/or pierced by Shrapnel from Adjacent Skin.
10. TUM. = Tumbled Entry

APPENDIX H

PHOTOGRAPHS - WET TANK FIRING

(a)



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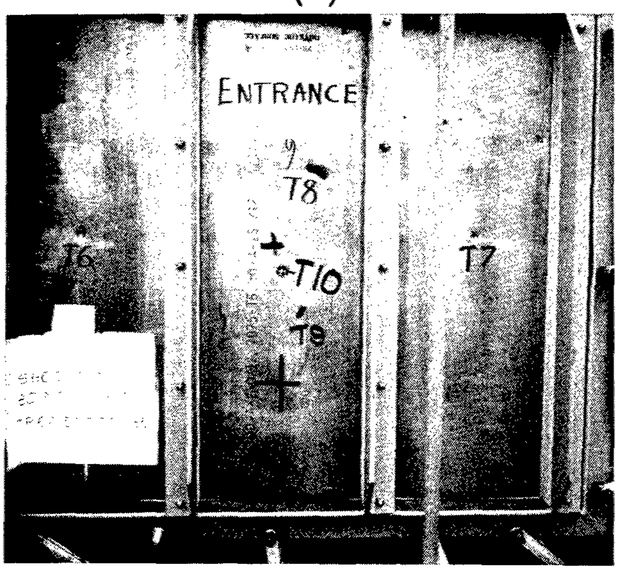

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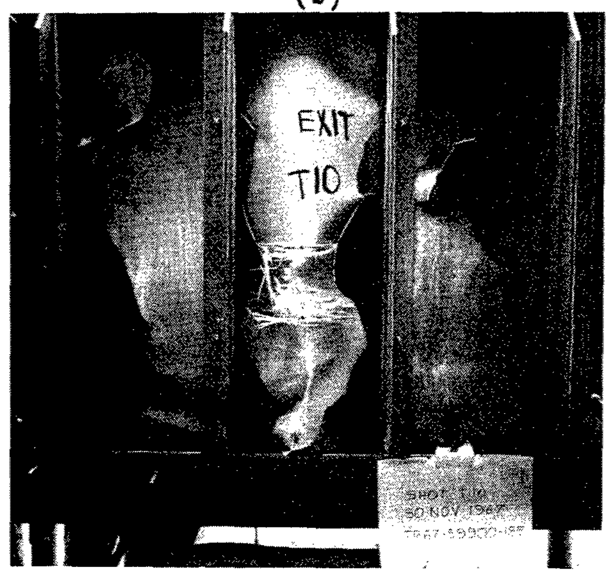

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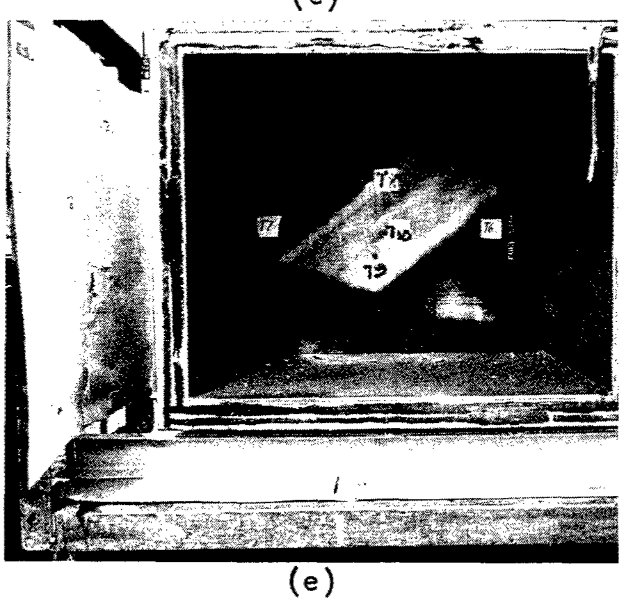

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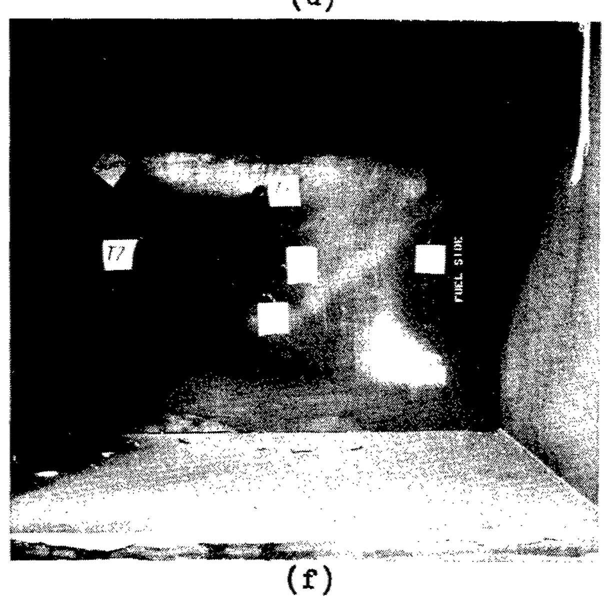


(f)

Figure H-1 Photographs, Blocks B8, B8.1

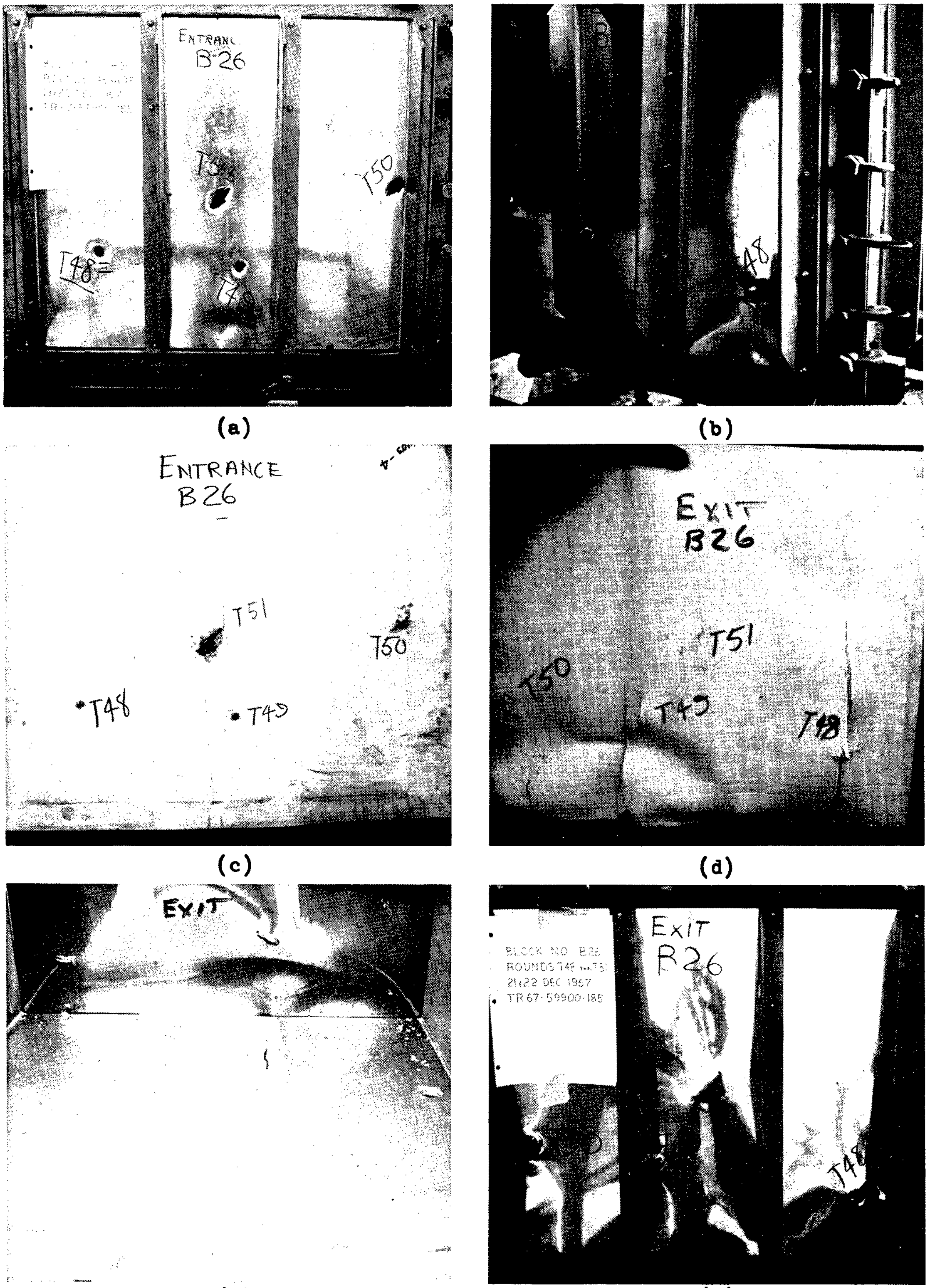
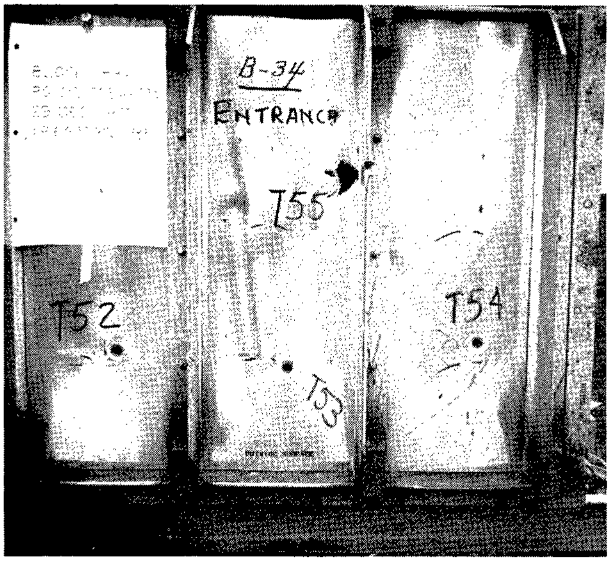


Figure H-2 Photographs, Block B26

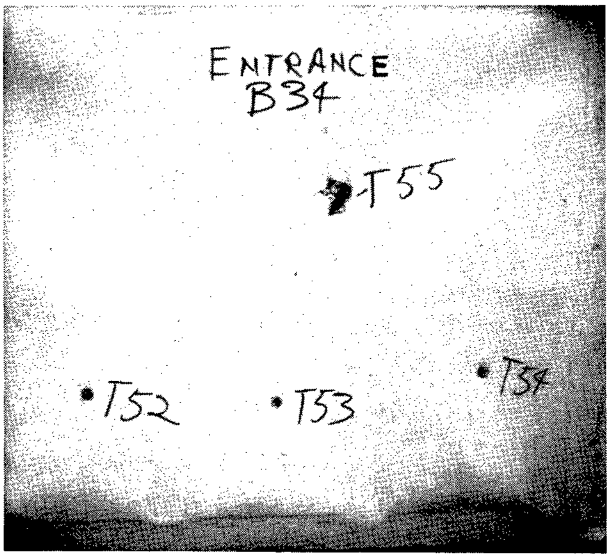
(a) (b)
(c) (d)
(e) (f)

Figure H-3 Photographs, Block B27



(a)

(b)



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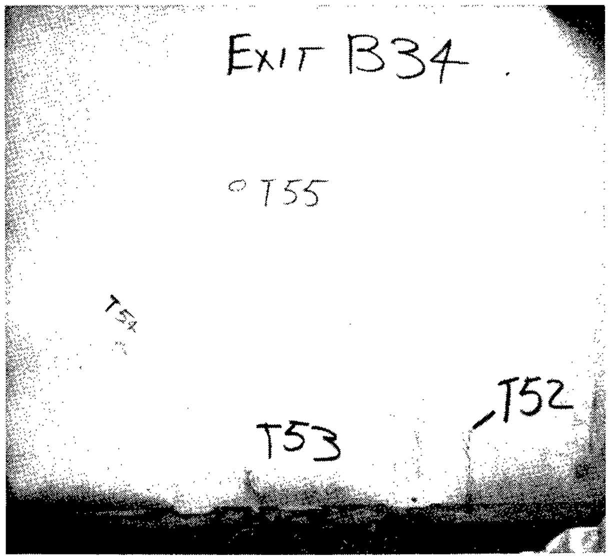

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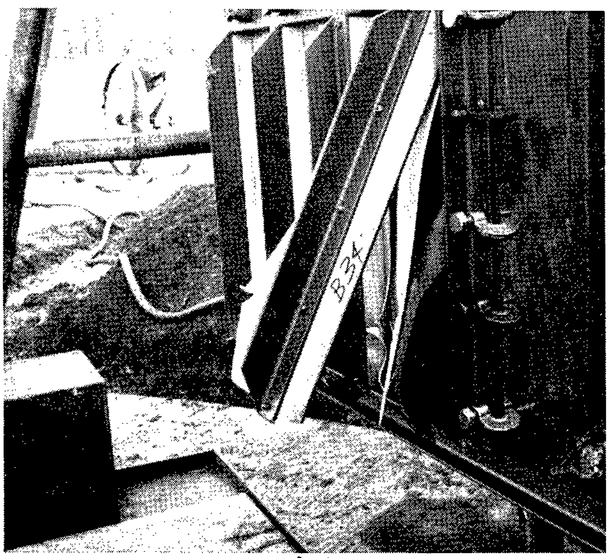


(e)

(f)

Figure H-4 Photographs, Block B34

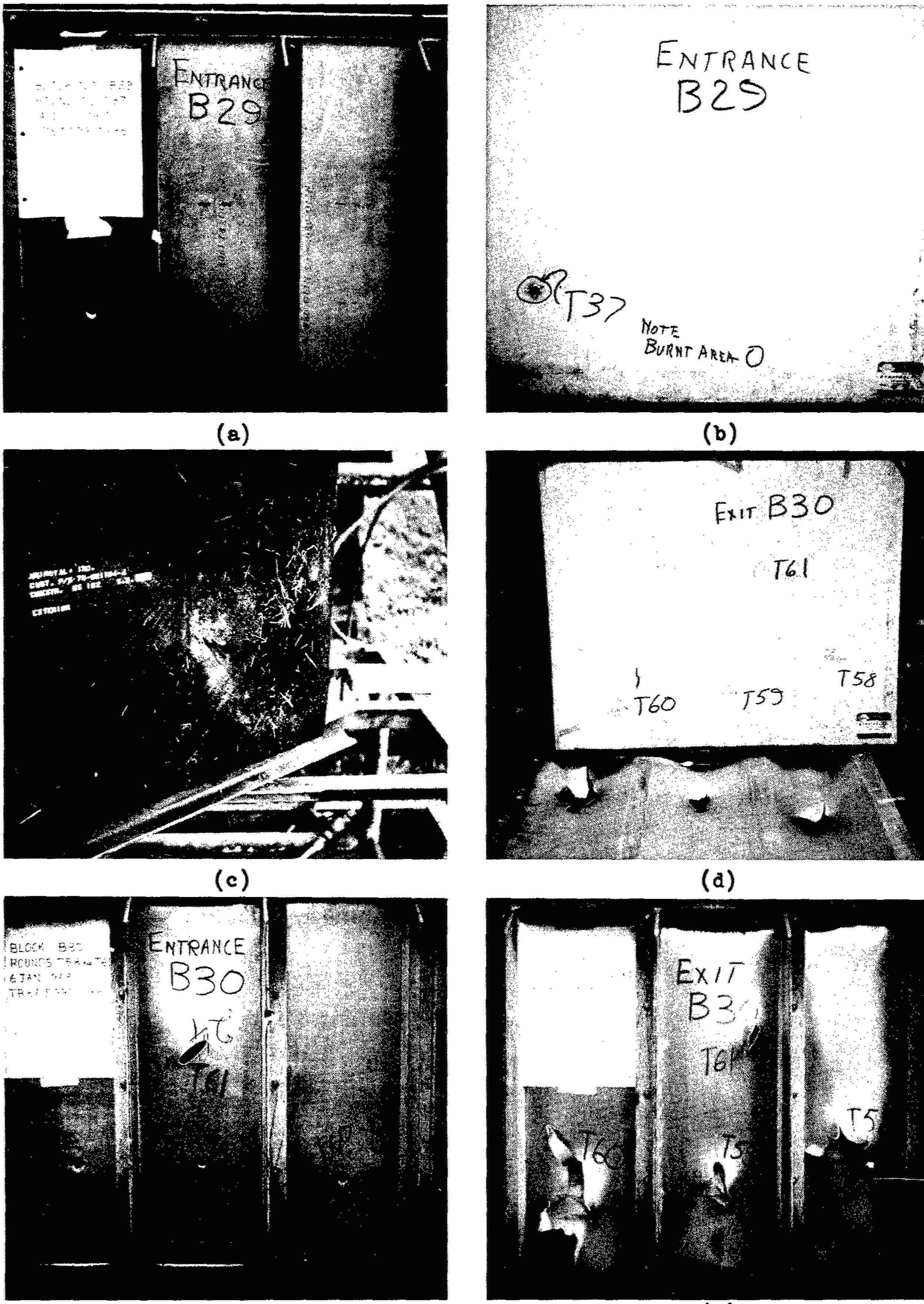


Figure H-5 Photographs, Blocks B29, B30

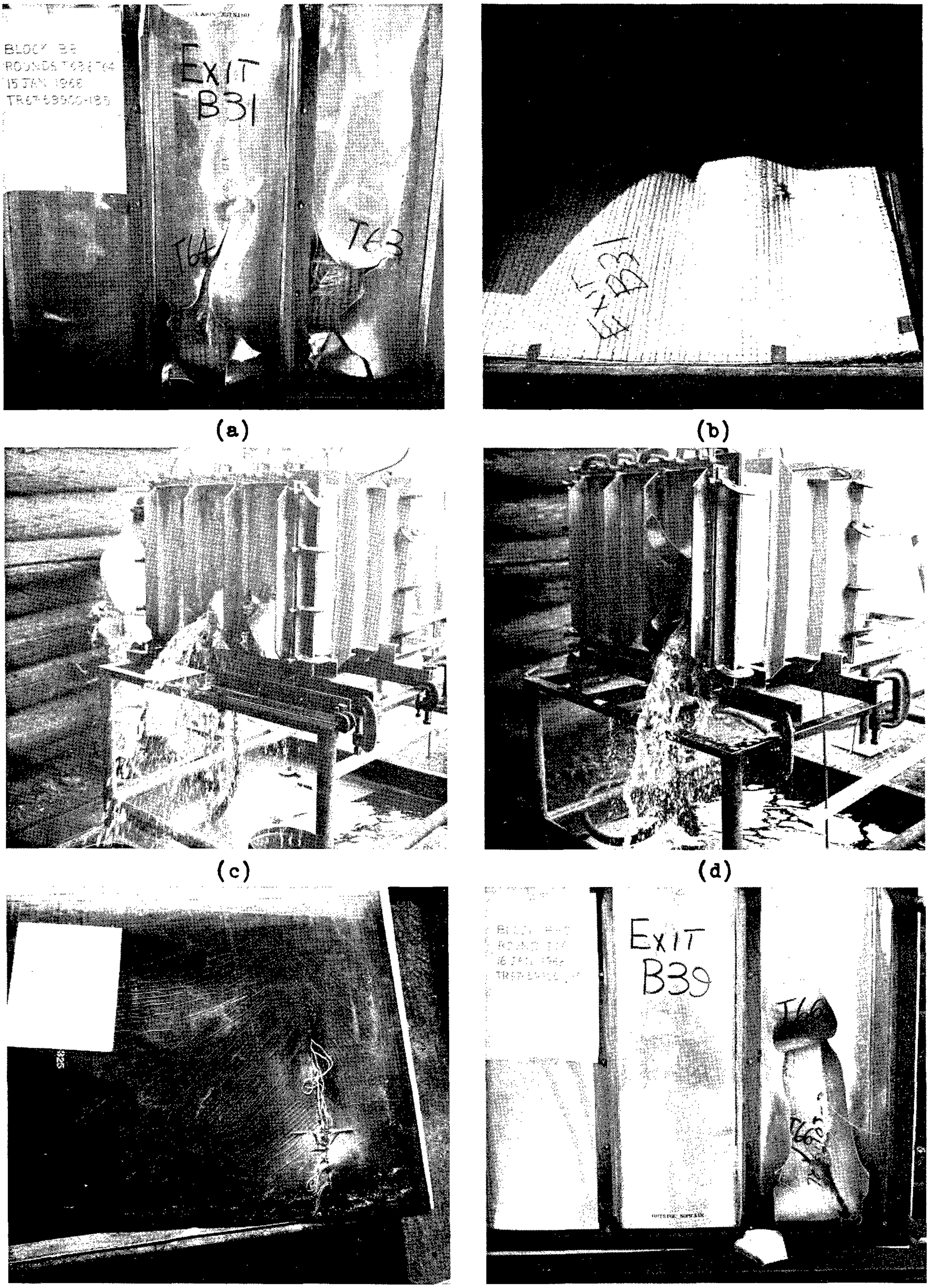


Figure H-6 Photographs, Blocks B31, B39

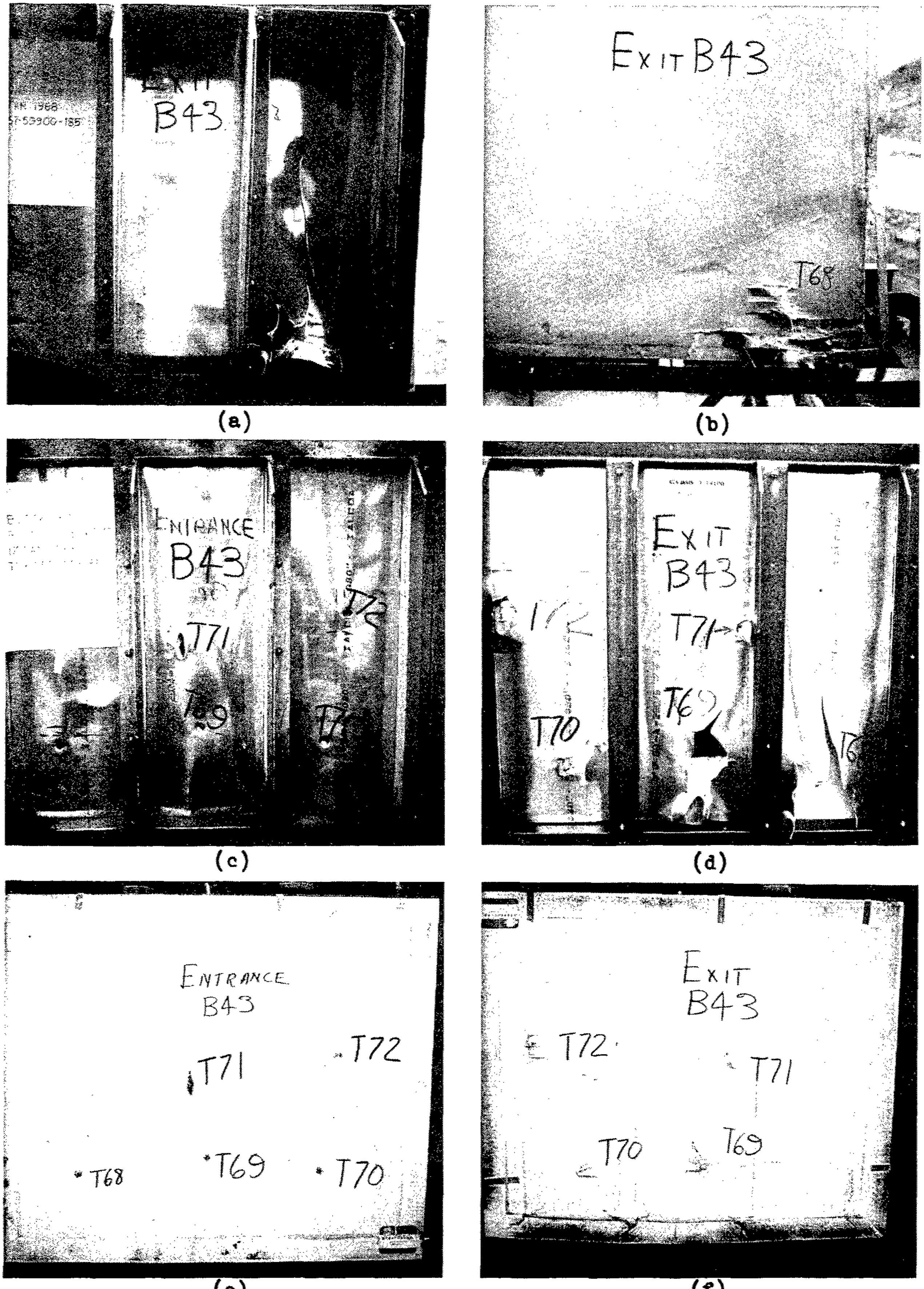
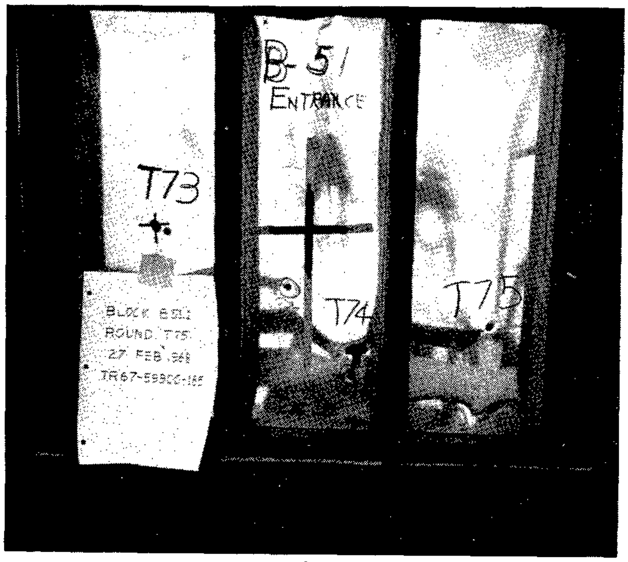
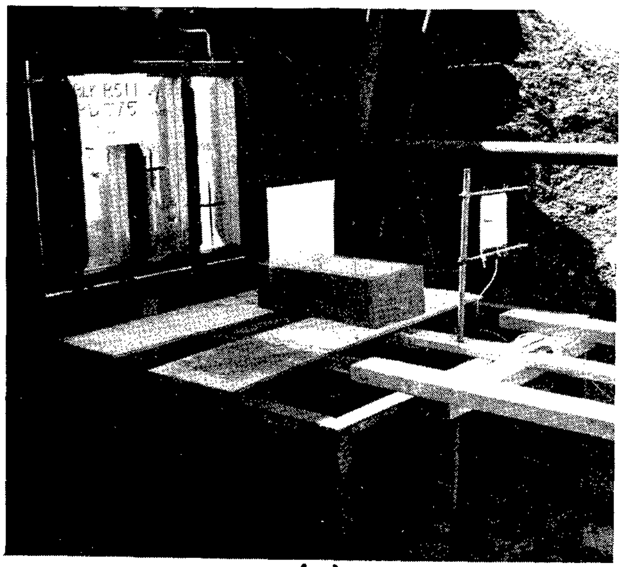


Figure H-7 Photographs, Block B43



(a)

(b)



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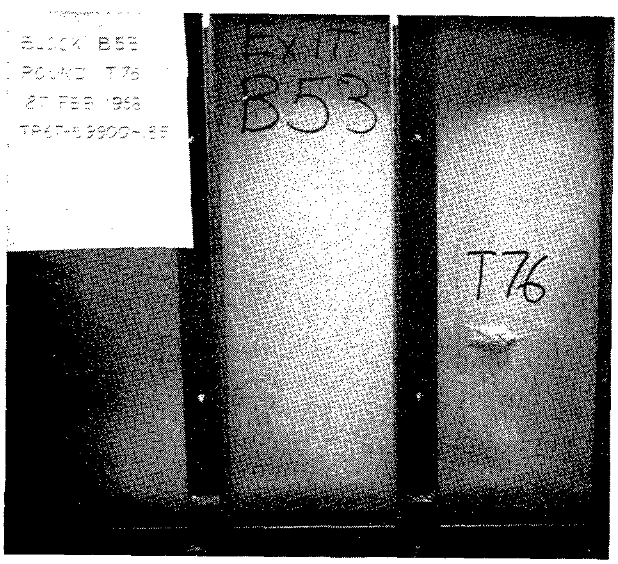
(d)



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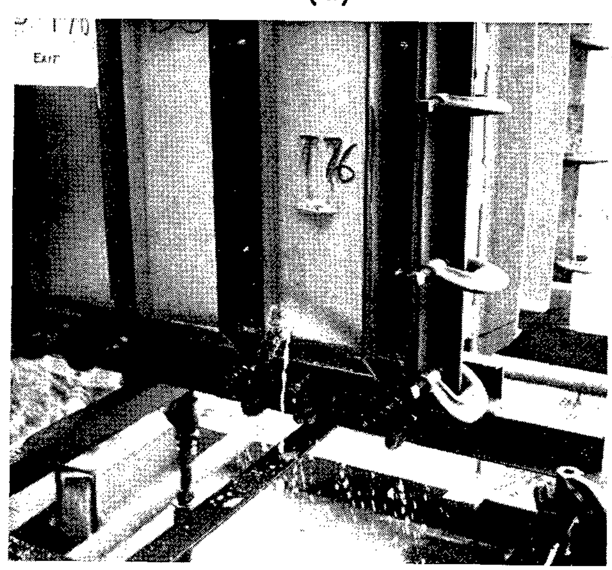
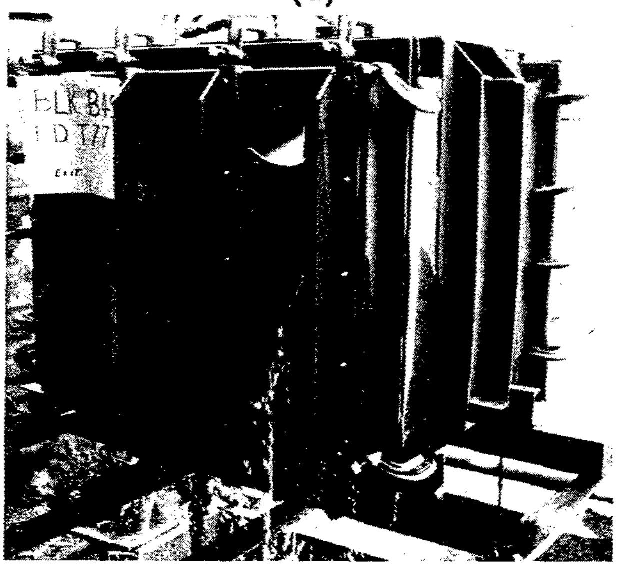


(f)

Figure H-8 **Photographs, Blocks B51, B51.1, B53, B53.1**

(a)

(b)



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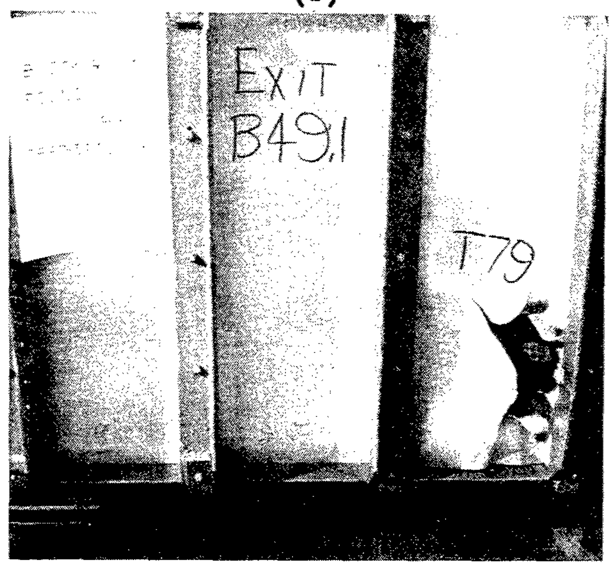

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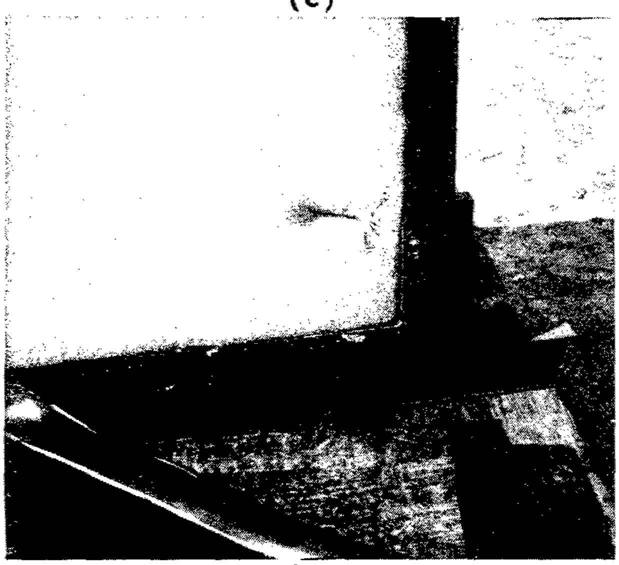
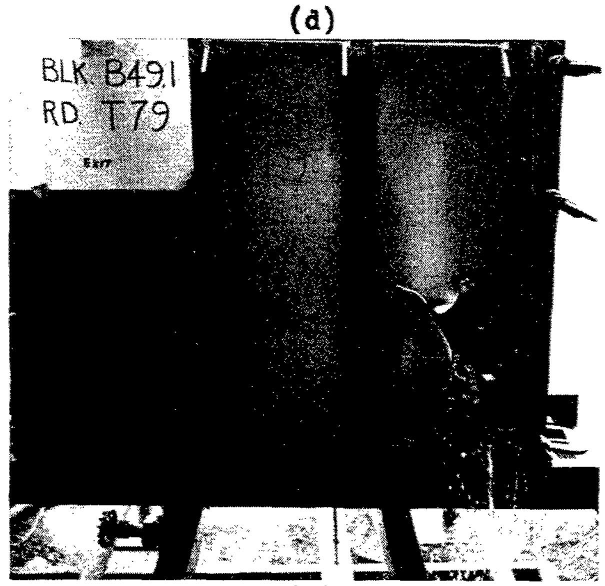
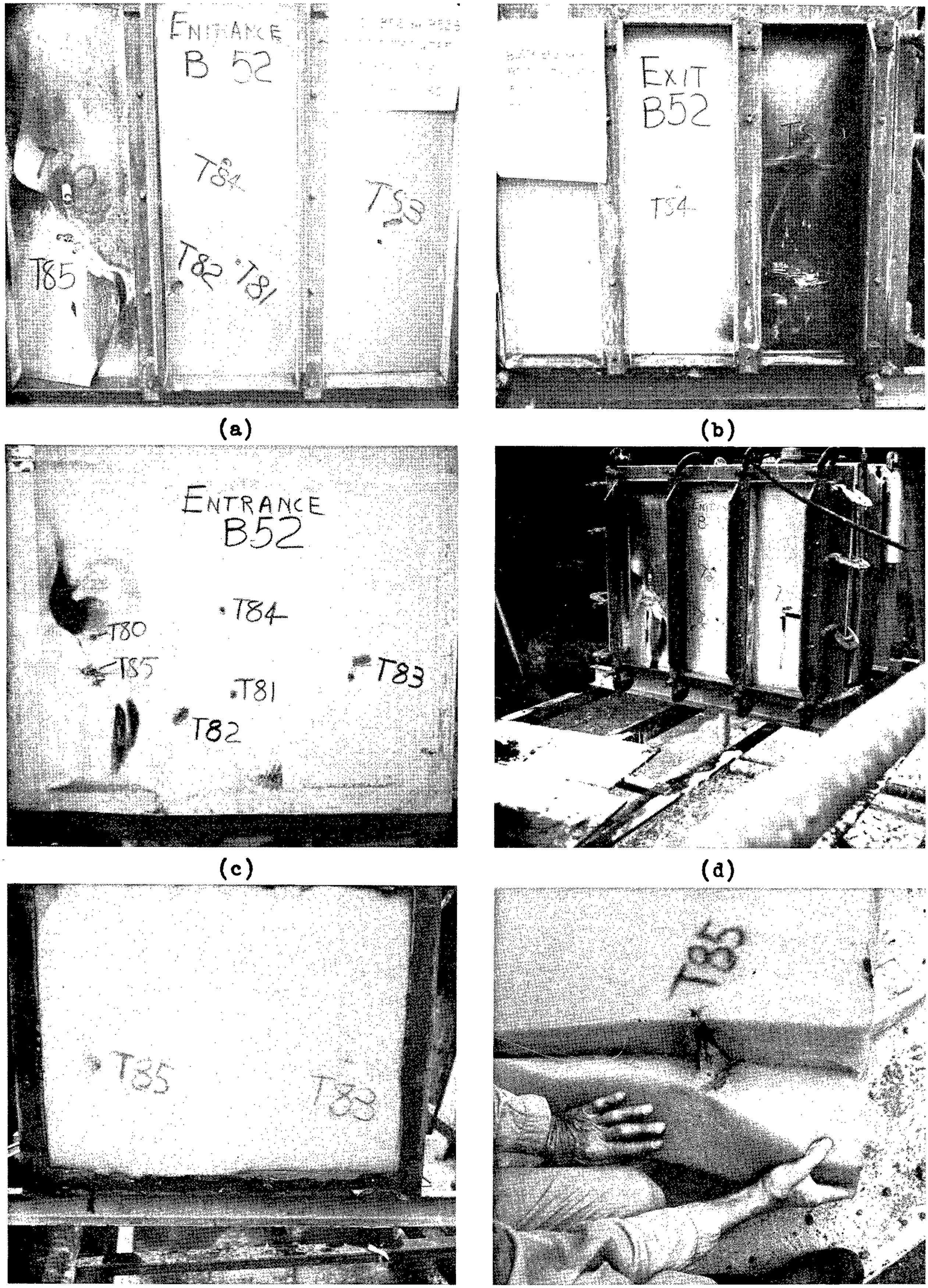


(e)



(f)

Figure H-9 Photographs, Blocks B49, B49.1

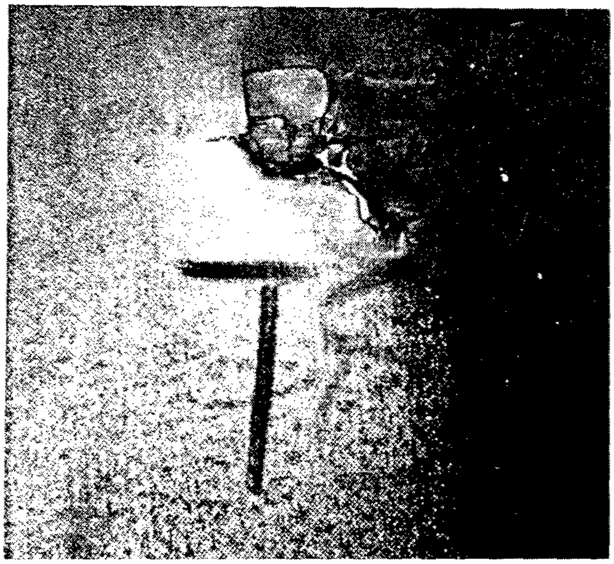


(a) (b)

(c) (d)

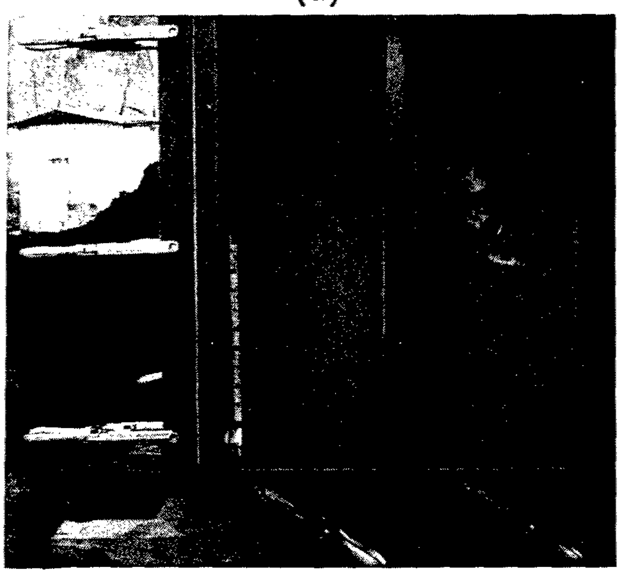
(e) (f)

Figure H-10 Photographs, Block B52



(a)

(b)



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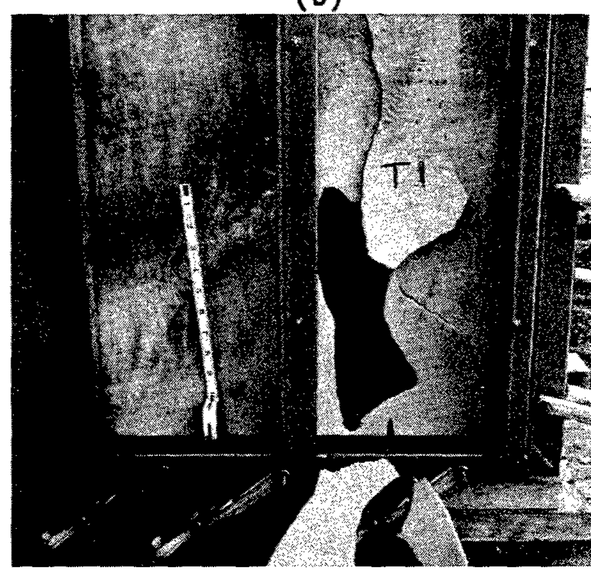
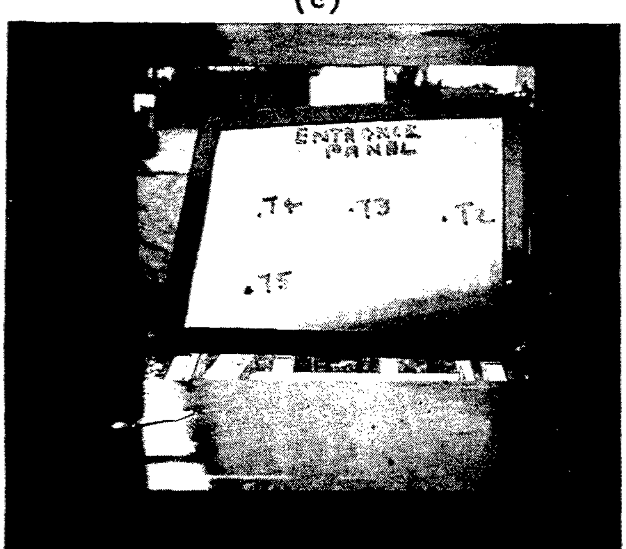


(d)



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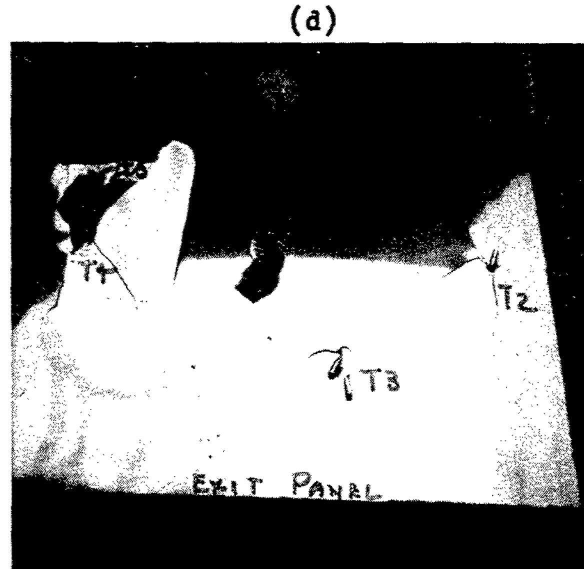
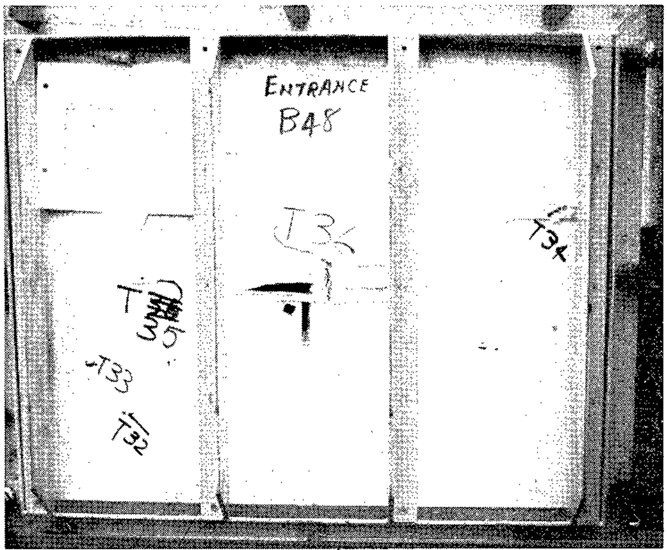


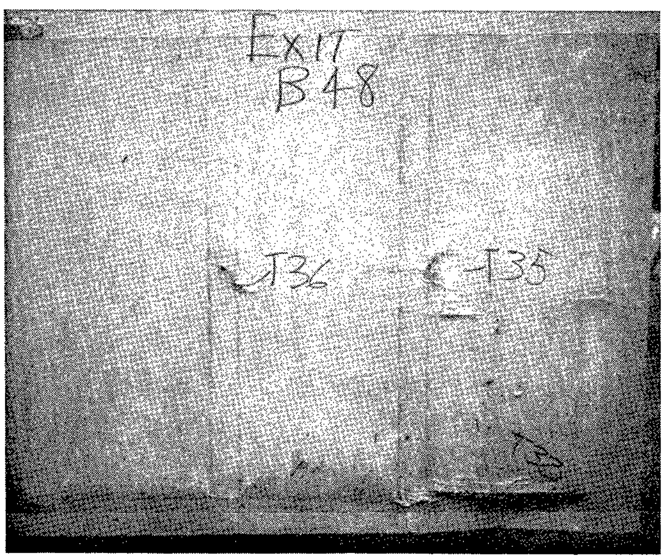
(f)

Figure H-11 Photographs, Blocks B12, B21, B22, B52



(a)

(b)



(c)

Figure H-12 Photographs, Block B48

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APPENDIX J

WET TANK TEST DATA SHEETS

Data sheets are arranged in numerical order according to the sequence of firing beginning with round T-1.

Each round is described in tabulated form and verbal description on the left hand side of the page and in sketches of the damage on the right hand side of the page.

BLOCK B12 ROUND NUMBER T1
DATE FIRED 21 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None
Skin Material N.A. Skin Gap –

PROJECTILE:

Caliber 30 Type AP Entry Straight
Velocity Approx. 2700 Ft/Sec Missed Reading

MATERIAL:

Backing Board –

Composite 3M Company HC-1101

Self Sealing –

RESULTS:

Entrance Seal Yes Exit Seal No
Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT 6 IN. BELOW FUEL SURFACE.

The composite material sealed damp immediately, with no coring.

EXIT: 10 IN BELOW THE FUEL SURFACE

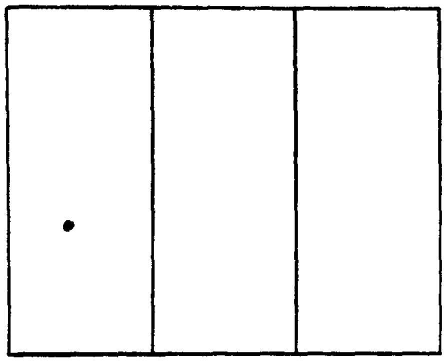
The composite material failed with a piece of material approximately 12 in x 4 in. coring out. Rest of the Panel was split.

No projectile marks were found on the material, thus indicating that the panel was failed by the pressure wave in front of the projectile. All the fuel (55 gal.) was lost.

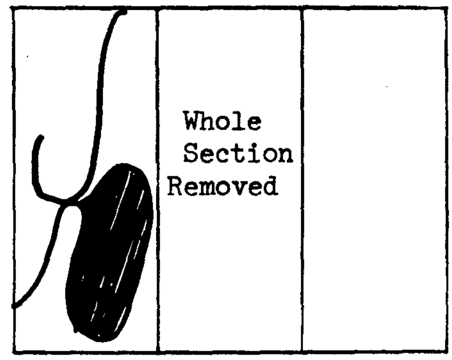
BLOCK NUMBER B 12

ROUND NUMBER T 1

ENTRANCE

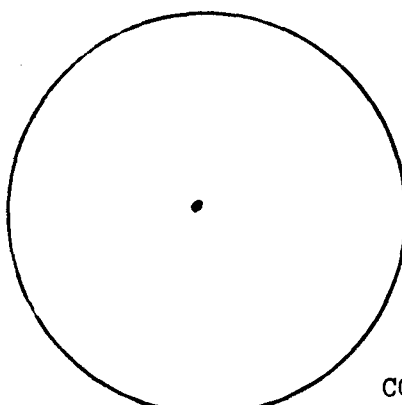


*EXIT

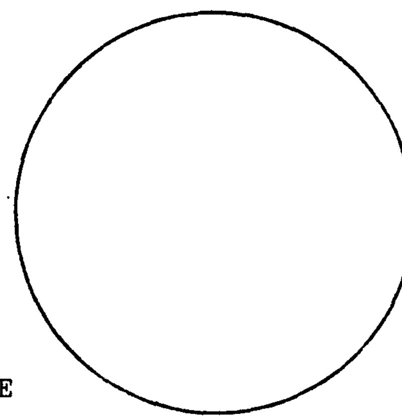


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE



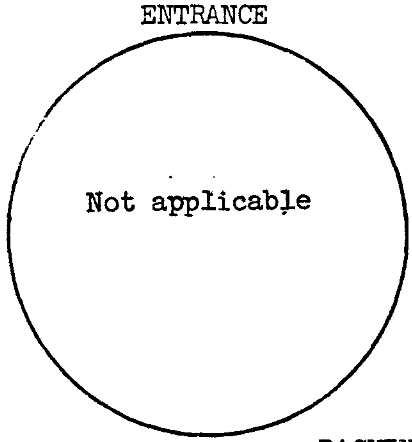
EXIT



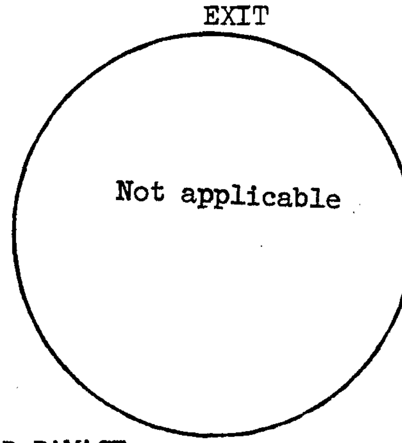
COMPOSITE

TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B21 ROUND NUMBER T2

DATE FIRED 27 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Coated Panel Skin & ~~Sealer Bonded~~ Skin Gap o

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2564 Ft/Sec

MATERIAL:

Backing Board -

Composite Goodyear FLC-1

Self Sealing -

RESULTS:

Entrance Seal Yes Exit Seal No exit

Entrance Cored No Exit Cored N. A.

COMMENTS:

ENTRANCE: STRAIGHT 6 IN. BELOW THE FUEL SURFACE

The self-sealing material sealed dry immediately. The skin was cored and petaled to the diameter of the projectile.

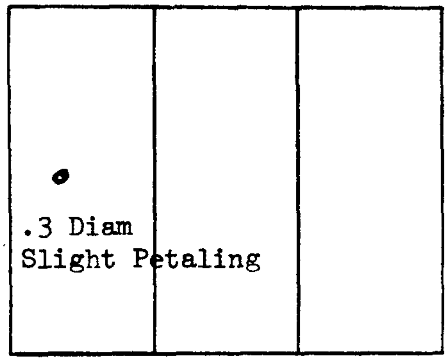
EXIT: NO EXIT OF PROJECTILE. ATTEMPT IN TUMBLE MODE 10 IN BELOW FLUID SURFACE

The self-sealing was not damaged. The skin was cracked badly.

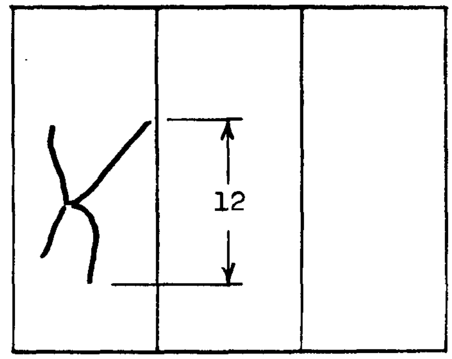
BLOCK NUMBER B 21

ROUND NUMBER T 2

ENTRANCE

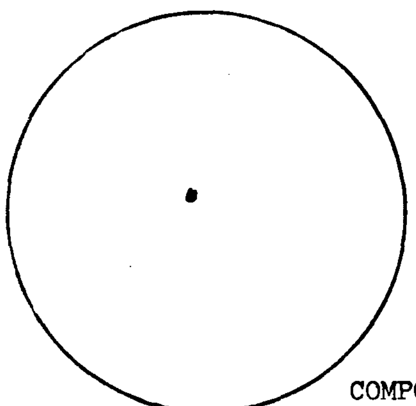


*EXIT

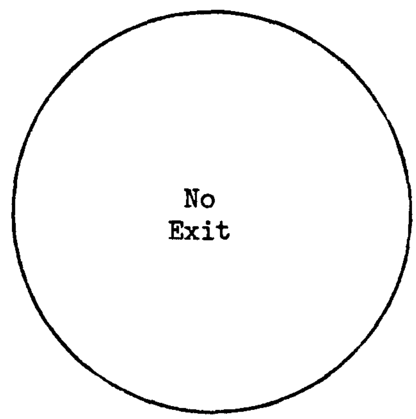


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

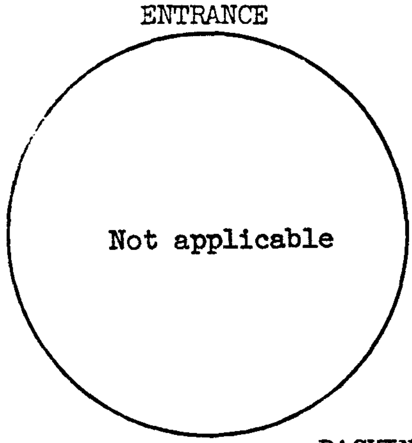


EXIT

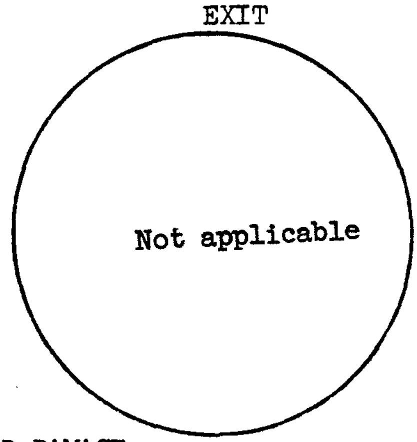


COMPOSITE
TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 21 ROUND NUMBER T 3

DATE FIRED 27 November 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material Coated Panel Skin and Sealer Bonded Skin Gap -------

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2667 Ft/Sec

MATERIAL:

Backing Board

Composite FLC-1 (Goodyear)

Self Sealing

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: Straight 5 inches below fuel surface.

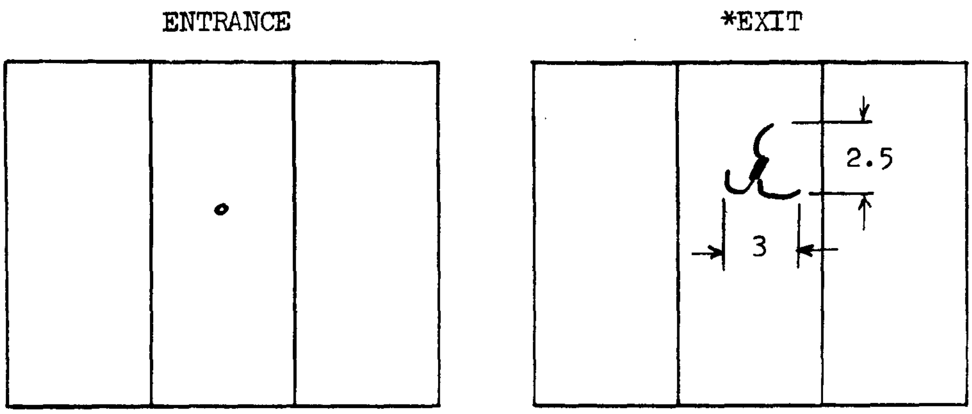
The sealing material sealed immediately with only a trace of fuel in the wound diameter. The skin was petaled and cored diameter of the projectile.

Exit: None. Attempt tumbled 2 inches below fuel surface.

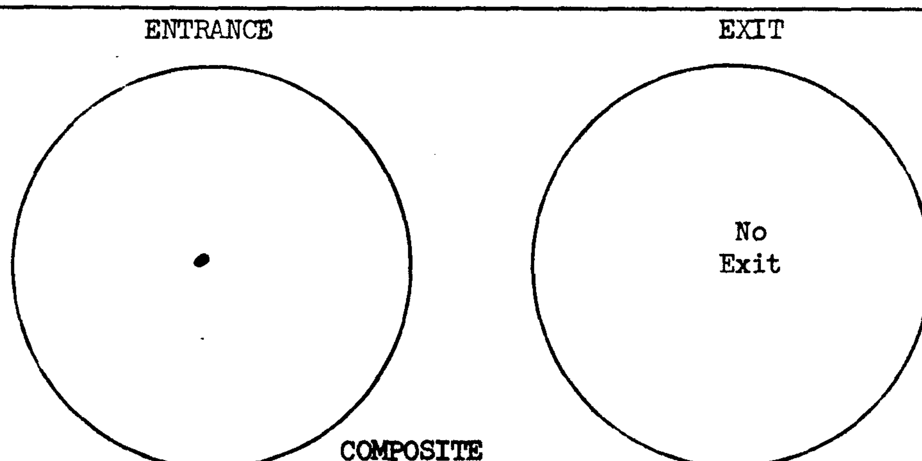
The sealing material suffered no damage. The skin was cracked but not penetrated. No leakage occurred.

BLOCK NUMBER B 21

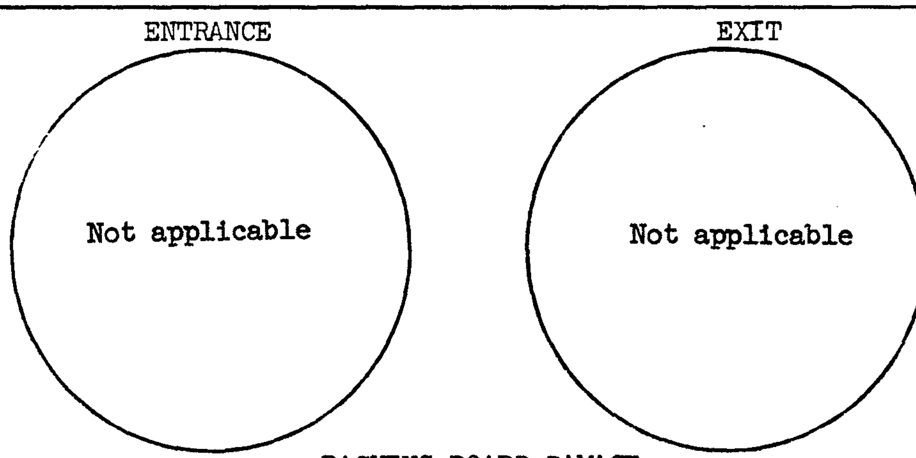
ROUND NUMBER T 3



SKIN PANEL DAMAGE AND DEFLECTIONS



COMPOSITE
TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B21 ROUND NUMBER T4

DATE FIRED 27 November 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material Coated Panel - Skin and Sealer bonded _ Skin Gap —

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2614 Ft/Sec

MATERIAL:

Backing Board ------------------------

Composite Goodyear FLC-1

Self Sealing ----------------------------

RESULTS:

Entrance Seal Yes Exit Seal No exit

Entrance Cored No Exit Cored N.A.

COMMENTS:

ENTRANCE: STRAIGHT 5.5 IN. BELOW FUEL SURFACE

The self-sealing material sealed immediately with only a trace of fuel in the wound. The skin was petaled and cored to diameter of projectile.

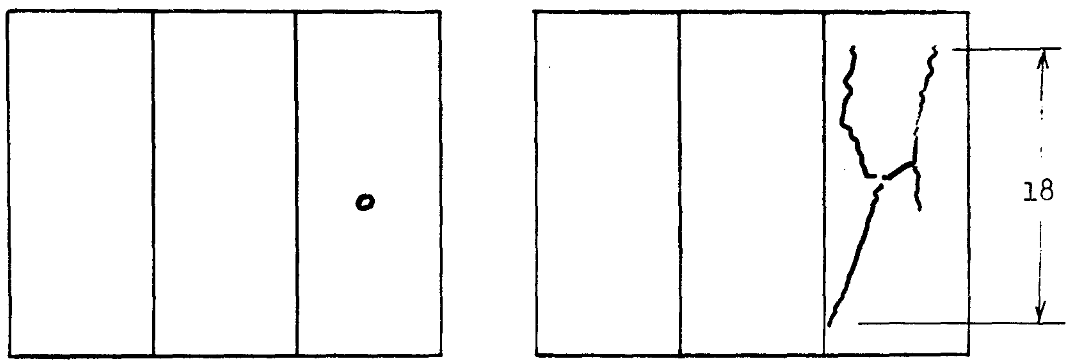
EXIT: TUMBLED ATTEMPT 6 IN. BELOW FUEL SURFACE

The Skin was badly cracked. The self-sealing was marked but not damaged . No leakage.

BLOCK NUMBER B 21

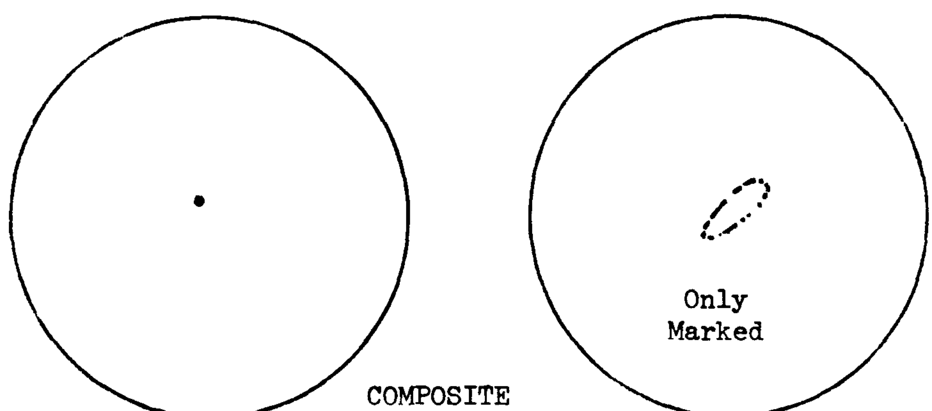
ROUND NUMBER T 4

ENTRANCE *EXIT



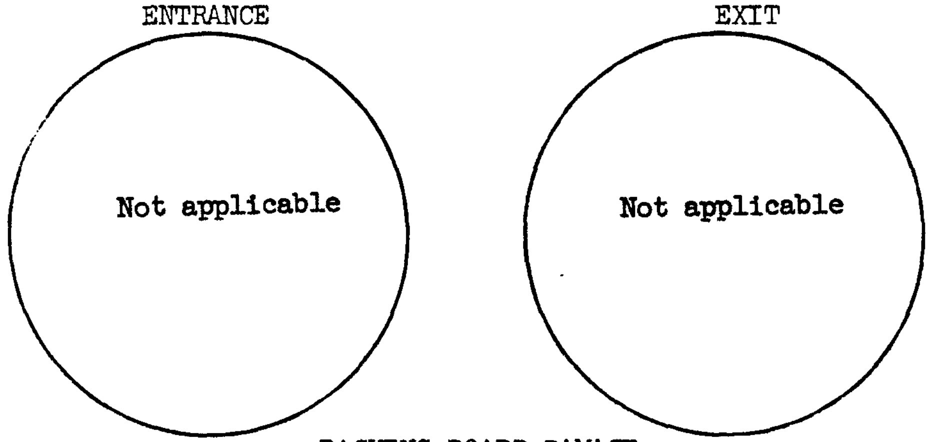
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



COMPOSITE
TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B22 ROUND NUMBER T5

DATE FIRED 27 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Coated Panel - Skin and Sealer bonded Skin Gap ------

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board ---------------------------

Composite Goodyear FLC-1

Self Sealing -----------------------

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored Yes

COMMENTS:

ENTRANCE: STRAIGHT 13 IN. BELOW FUEL SURFACE

The self-sealing material sealed damp immediately with a spot 2" x 1" showing dampness. The skin was cored and petaled.

EXIT: PARTIALLY TUMBLED.

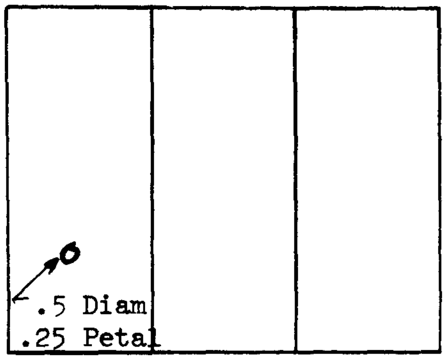
The self-sealing material was cored and metal was petaled into the wound. There was no possibility of a seal.

The skin was broken up badly with a large portion knocked out between wounds of T4 and T5.

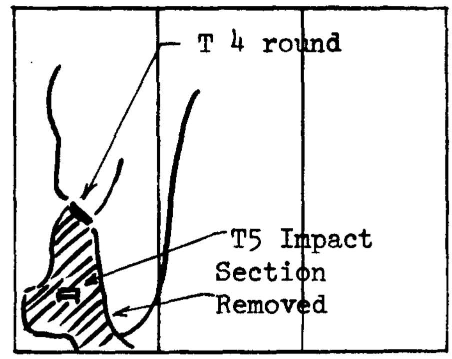
BLOCK NUMBER B 22

ROUND NUMBER T 5

ENTRANCE

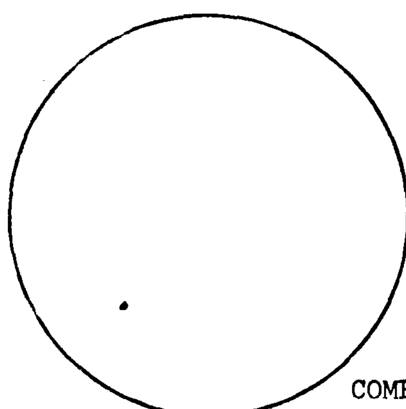


*EXIT

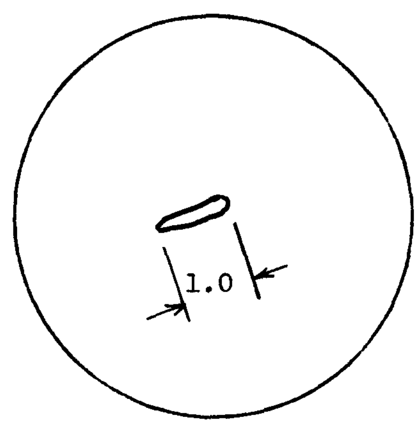


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

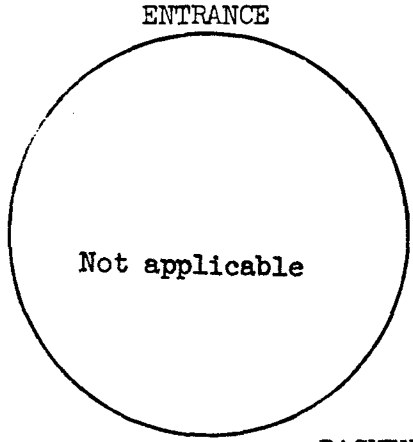


EXIT

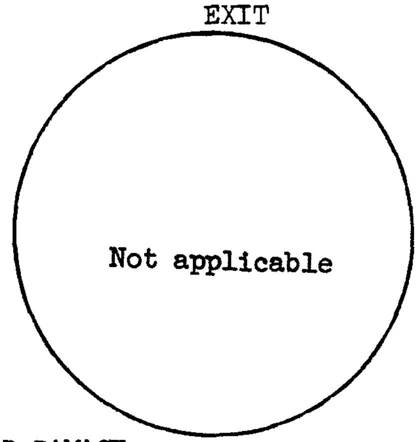


COMPOSITE
TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B8 ROUND NUMBER T6

DATE FIRED 28 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 0

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2632 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal .30)

Composite --------------------------------

Self Sealing Goodyear FTL 11-3 (Cal .30)

RESULTS:

Entrance Seal Yes Exit Seal Yes

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT 5 IN. BELOW FUEL SURFACE

The skin was cored to diameter of projectile. There was no petaling present.

The backing board was frayed. The self sealing material sealed with no leakage.

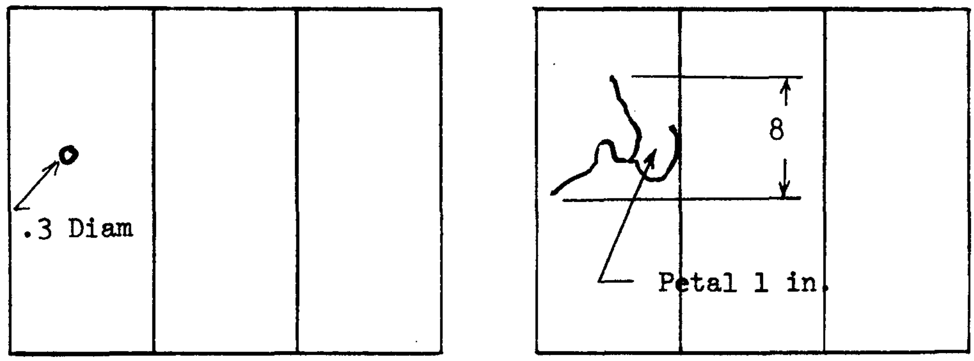
EXIT: TUMBLED 5 IN. BELOW FUEL SURFACE

The skin was torn badly. The backing board was frayed but maintained support. The self-sealing material was slit but sealed damp immediately.

BLOCK NUMBER B 8

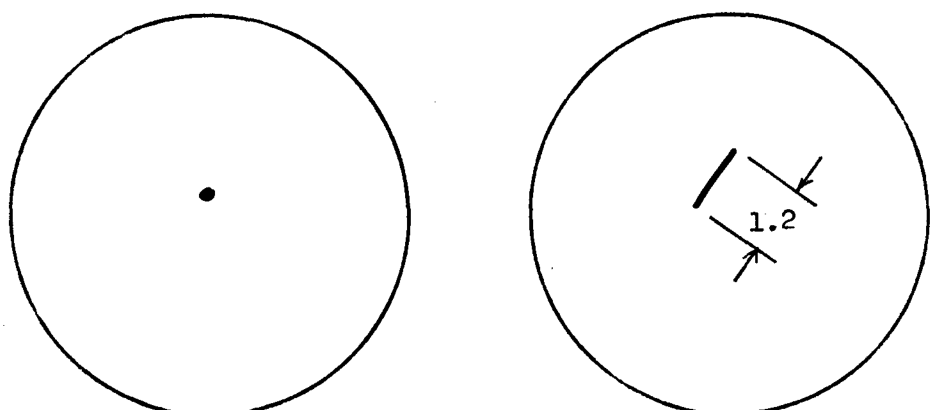
ROUND NUMBER T 6

ENTRANCE *EXIT



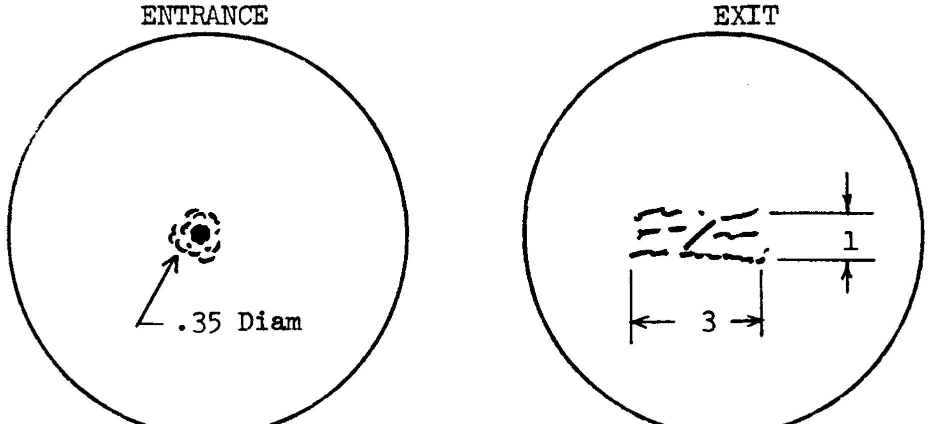
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B8 ROUND NUMBER T7

DATE FIRED 28 November 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 0

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2667 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal .30)

Composite ---------------------------------

Self Sealing Goodyear Tire FTL 11-3 (Cal.30)

RESULTS:

Entrance Seal Yes Exit Seal Yes

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT 13 IN. HIGH 5 IN. BELOW FUEL SURFACE

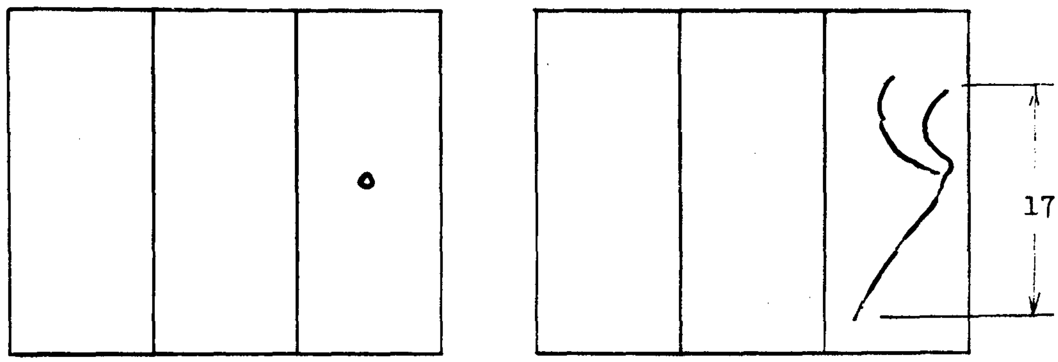
The skin was cored to diameter of projectile. No petals. The backing board frayed very little. The self-sealing sealed dry immediately.

EXIT: TUMBLED 16 IN HIGH 2 IN. BELOW FUEL SURFACE

The skin was split but not cored. The backing board was frayed slightly. The self-sealing material was slit but did seal damp immediately.

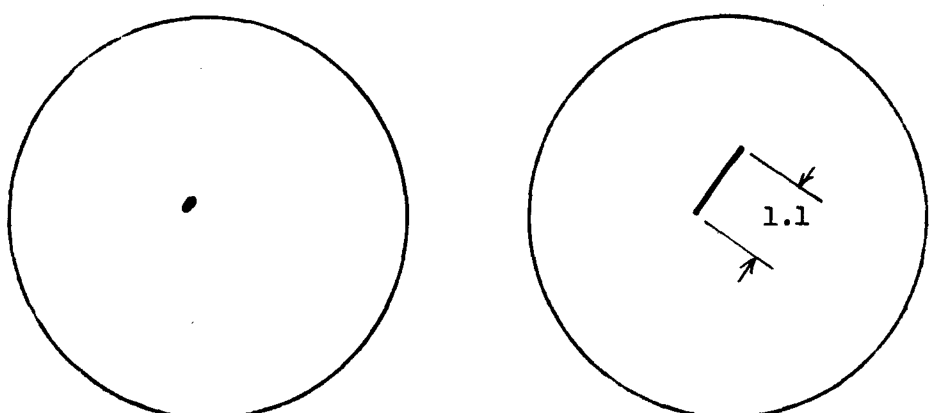
BLOCK NUMBER B 8
ROUND NUMBER T 7

ENTRANCE *EXIT



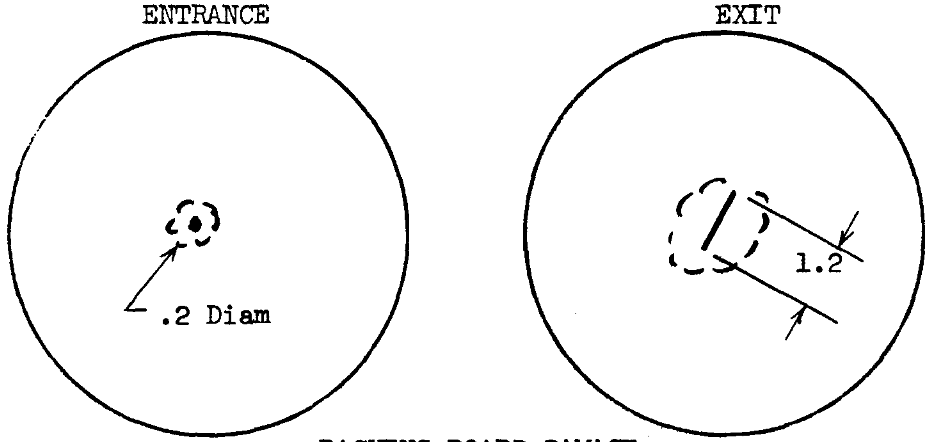
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 8 ROUND NUMBER T 8

DATE FIRED 29 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity 2454 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite --------------------

Self Sealing Goodyear Tire FTL 11-3 (Cal. 30)

RESULTS:

Entrance Seal yes (1 minute) Exit Seal No exit

Entrance Cored no Exit Cored N. A.

COMMENTS:

Entrance: Tumbled 2 1/2 inches below the fuel surface.

The skin was cored and petaled .25 inches high. The backing board was cored the size of the tumbled round. The self-sealing material seeped for 1 minute before obtaining a damp seal. The leakage was not measurable.

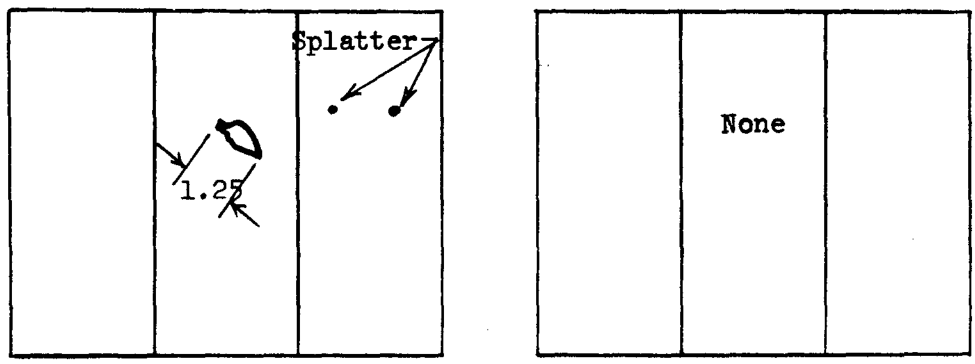
Exit: None

Only the self-sealing was cut on the exit panel.

BLOCK NUMBER B 8

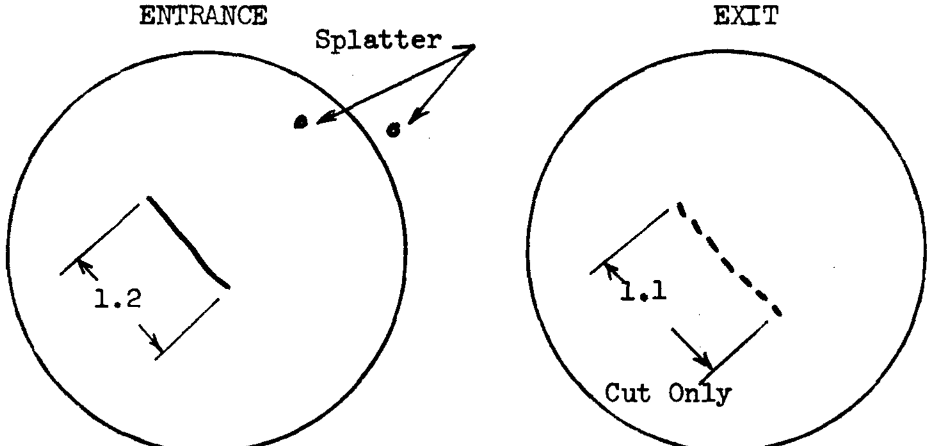
ROUND NUMBER T 8

ENTRANCE *EXIT



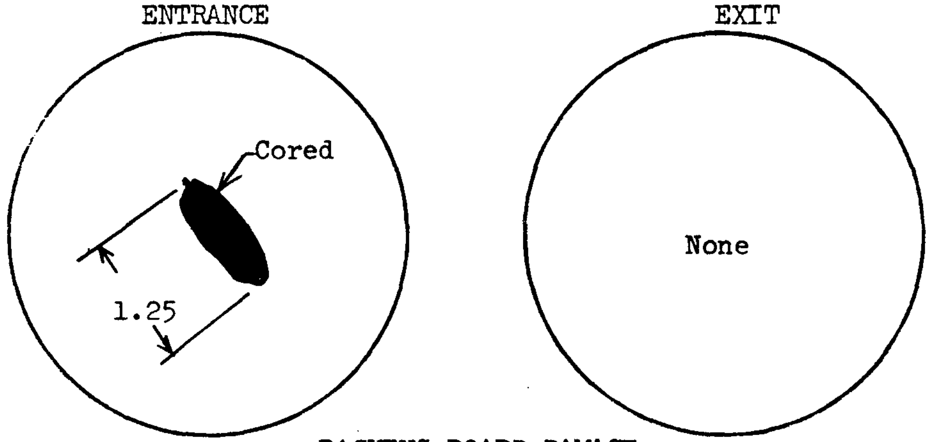
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 8 ROUND NUMBER T 9

DATE FIRED 29 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity 2516 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite ---------------

Self Sealing Goodyear Tire FTL 11-3 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: About one-half tumbled 9.5 inches below the fuel surface.

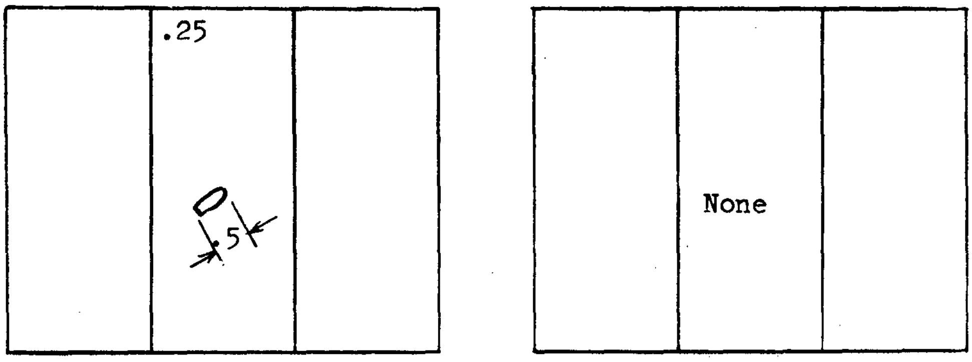
The skin was cored full size of the hole and deflected about .25 inches. The backing board was frayed. The self-sealing material sealed immediately with only a trace of fuel leakage.

Exit: None

BLOCK NUMBER B 8

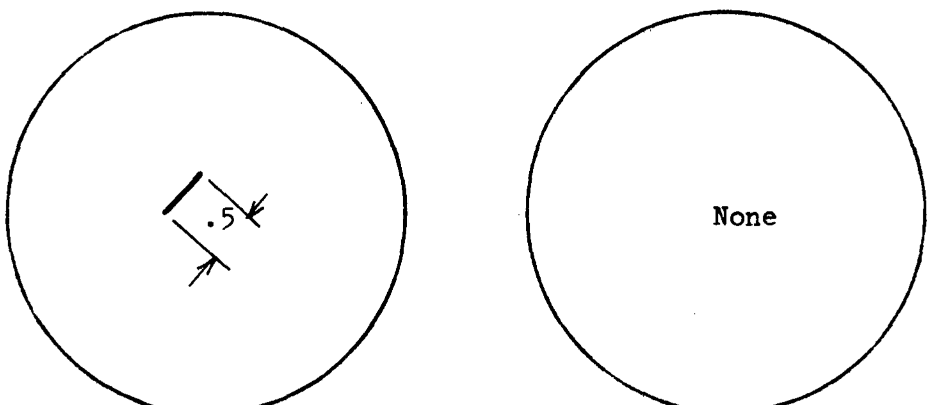
ROUND NUMBER T 9

ENTRANCE *EXIT



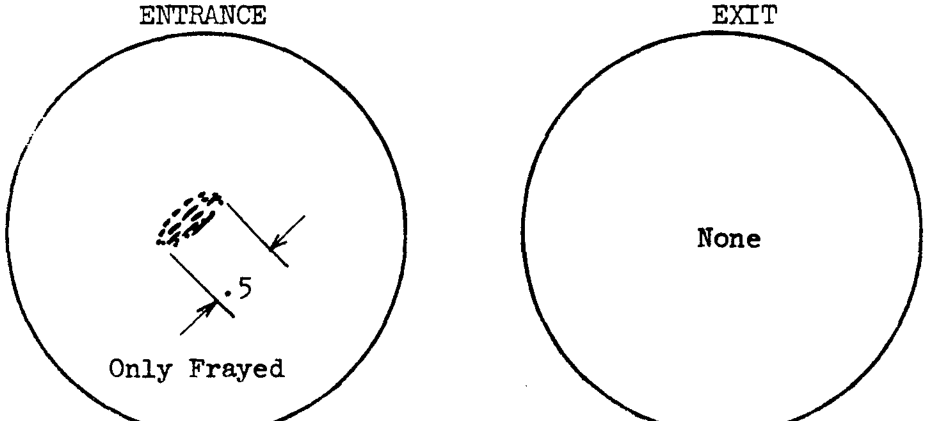
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 8.1 ROUND NUMBER T 10

DATE FIRED 30 November 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2920 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite --------------------

Self Sealing Goodyear Tire FTL 11-3 (Cal. 0)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored slightly

COMMENTS:

Entrance: Straight 6 inches below fuel surface.

The skin was cored and cracked slightly. The backing board was just frayed. The self-sealing material sealed immediately with no leakage.

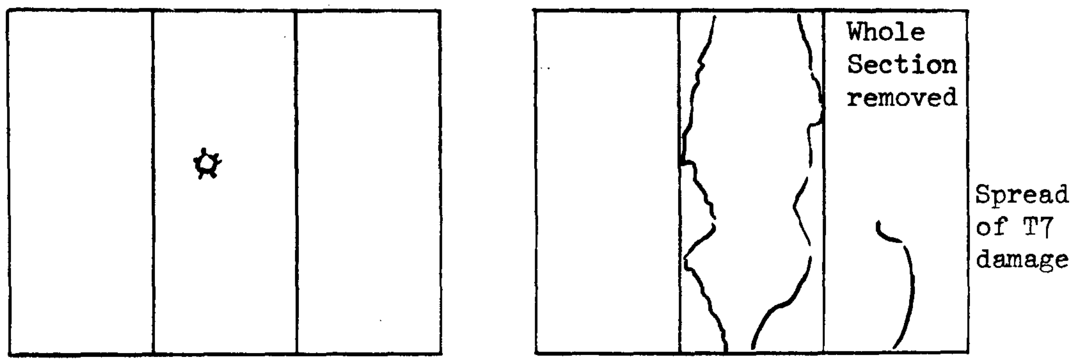
Exit: Tumbled 9 inches below fuel surface.

The skin was failed totally with a section 7.5 inches wide and 24 inches long removed in several pieces. The crack from round T 7 spread out to edge of the panel. The backing board was frayed and buckled 2 1/2 inches high. The self-sealing material was cored slightly and was not supported by the backing board. Cavity leaked approximately 38 - 40 gallons in 2 minutes.

BLOCK NUMBER B 8.1

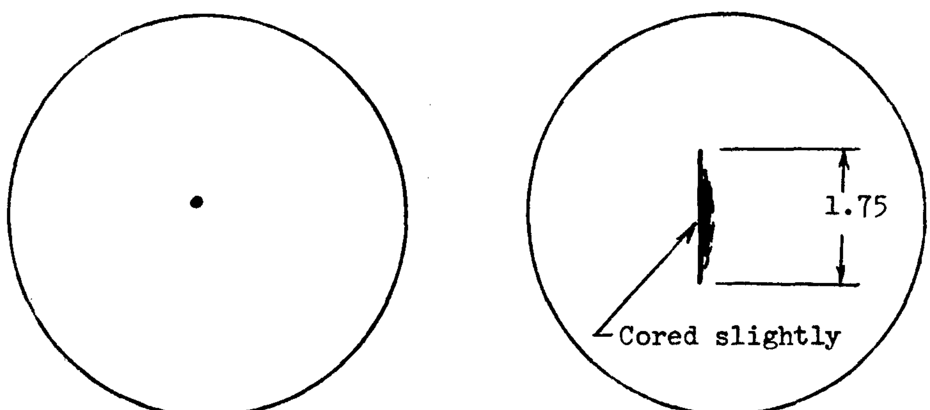
ROUND NUMBER T 10

ENTRANCE *EXIT



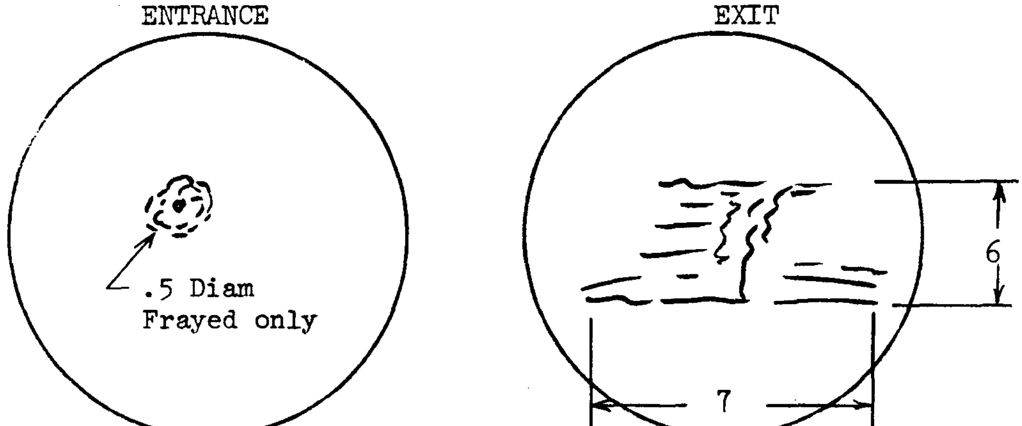
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 18 ROUND NUMBER T 11

DATE FIRED 1 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 1.25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite ----------------

Self Sealing Uniroyal US-180 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored yes

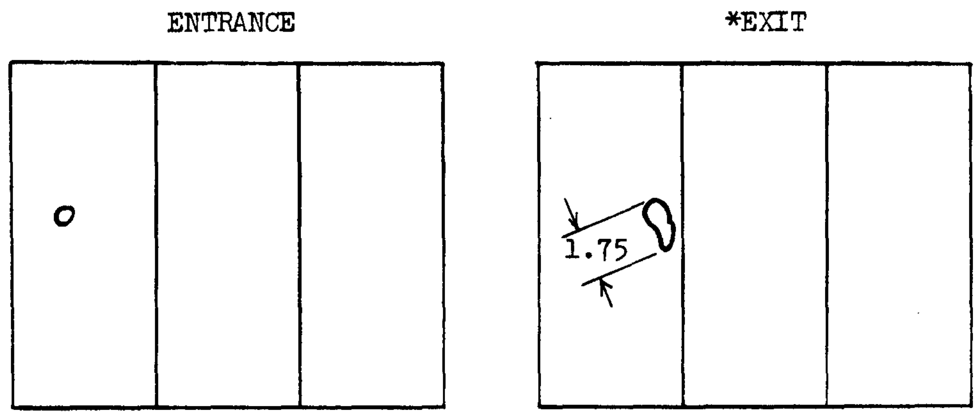
COMMENTS:

Entrance: Straight 4.5 inches below the fuel surface.
Observers saw a flash on the entrance skin. The skin was cored. The backing board was frayed. The self-sealing material sealed immediately with no leakage.

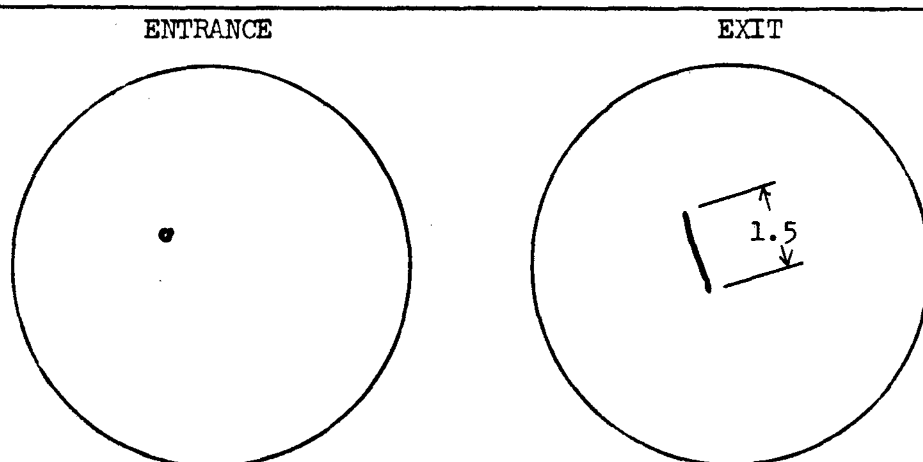
Exit: Partially tumbled 4 inches below the fuel surface.
The skin was cored. The backing board was cored. The self-sealing material was cored slightly. It was a reduced rate type leakage. Flanges let go so could not establish a rate.

BLOCK NUMBER B 18

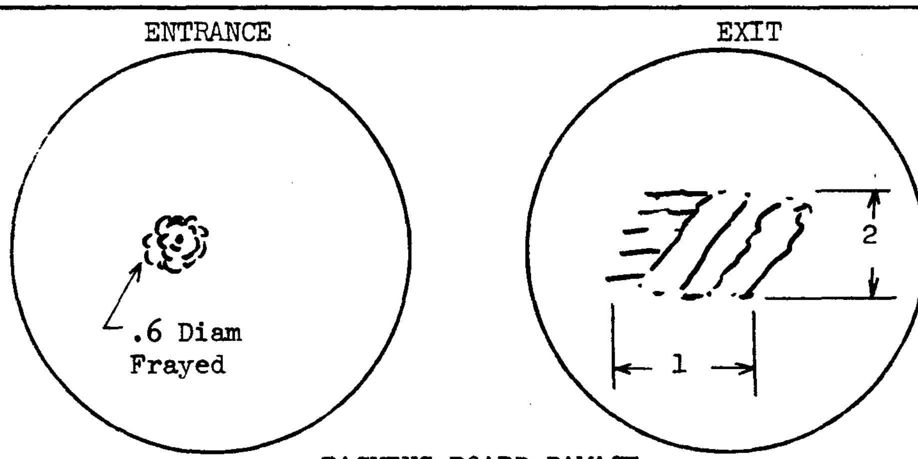
ROUND NUMBER T 11



SKIN PANEL DAMAGE AND DEFLECTIONS



TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 18 ROUND NUMBER T 12

DATE FIRED 1 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 1.25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2837 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite ----------------

Self Sealing Uniroyal US-180 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored yes

COMMENTS:

Entrance: Straight 5 inches below fuel surface.

A flash was seen on entrance skin when impacted by the projectile. The skin was cored as was the backing board. The self-sealing material sealed instantly.

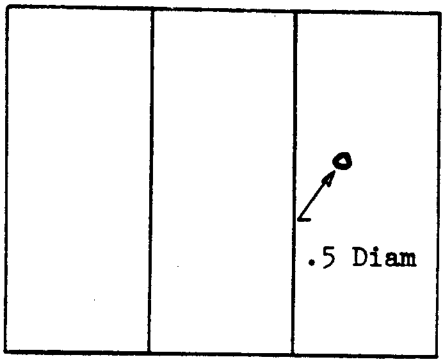
Exit: 3/4 tumble 6 inches below fuel.

The skin was completely destroyed. The backing board failed with a 4 in. x 6 in. cored section. The self-sealing material was also slightly cored and leaked at a reduced rate. Flange again let go so could not establish a rate.

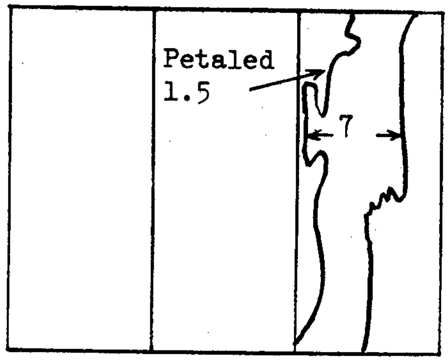
BLOCK NUMBER B 18

ROUND NUMBER T 12

ENTRANCE

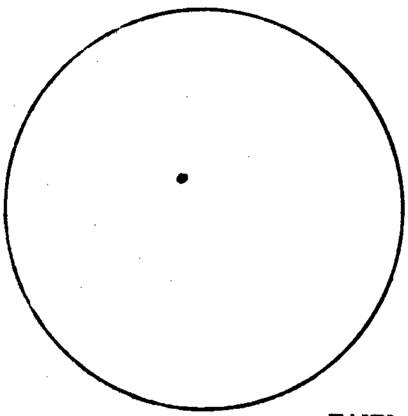


*EXIT

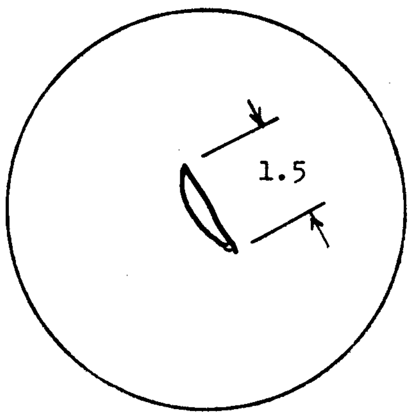


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

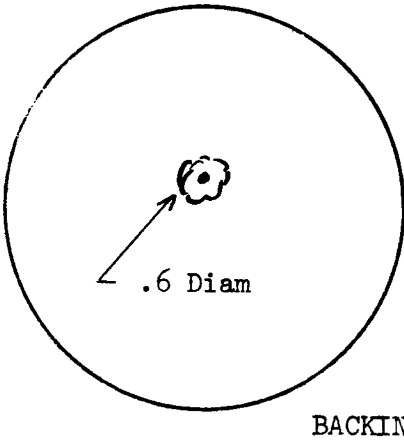


EXIT

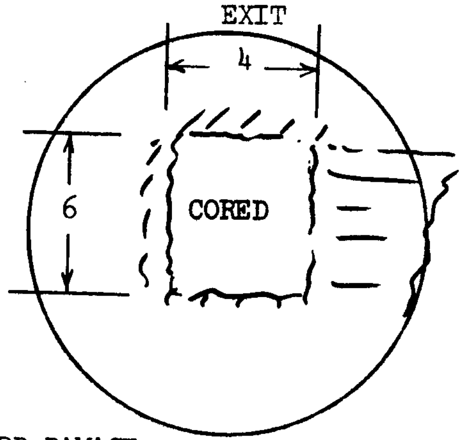


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 10 ROUND NUMBER T 13

DATE FIRED 2 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.080) Skin Gap .6 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2667 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite ----------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

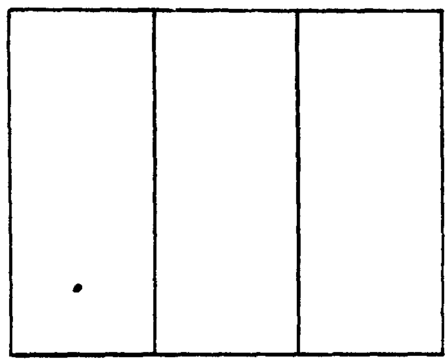
COMMENTS:

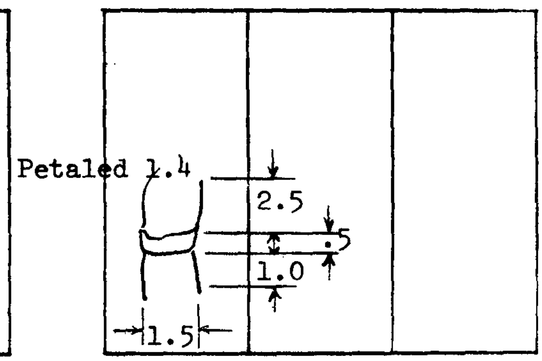
The fuel tank was shot with the 2 inch vent cap off. Some fuel was splashed out of the vent when the tank was hit by the projectile. The projectile entrance was straight 12 inches below the fuel surface, and the exit was fully tumbled 9 inches below the fuel surface. The entrance skin was cored, the backing board just frayed with no trace of fuel leaking in the self-sealing material. The exit wound sealed with only a trace of fuel escaping. The exit skin was petaled to a height of 1.4 inches with no coring. The backing board was frayed. Observers noted a flash on the entrance of the projectile at the skin.

BLOCK NUMBER B 10

ROUND NUMBER T 13

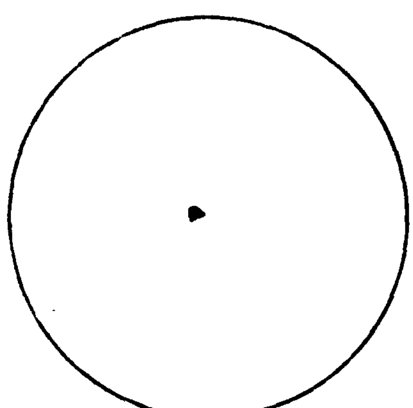
ENTRANCE	*EXIT

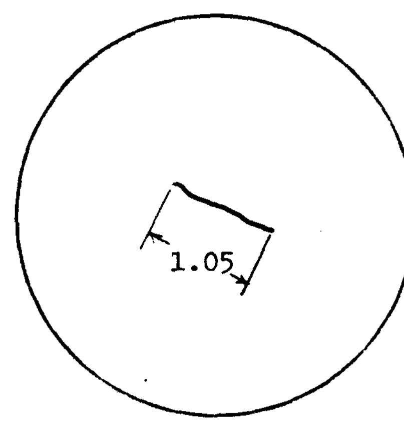




SKIN PANEL DAMAGE AND DEFLECTIONS

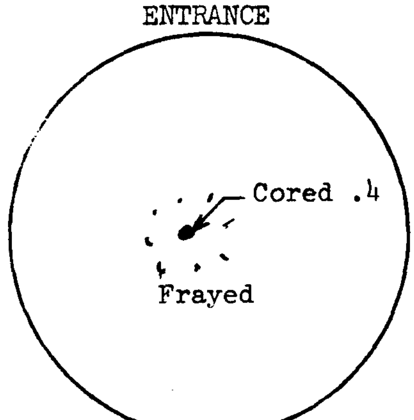
ENTRANCE	EXIT

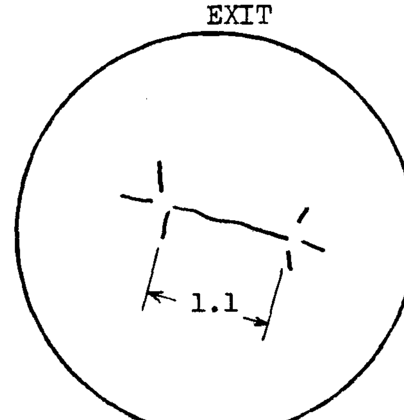




TANK DAMAGE

ENTRANCE	EXIT





BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 10 ROUND NUMBER T 14

DATE FIRED 2 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 (.080) Skin Gap .6 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2649 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite ----------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight

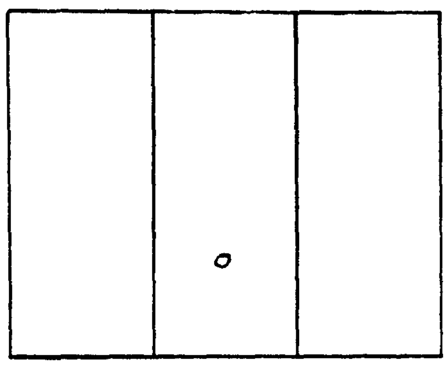
The metal cored slightly. The backing board frayed. The self-sealing material sealed immediately with no trace of fuel.

Exit: No exit of projectile through skin, but leakage occurred. The backing board was slit and the self-sealing material was slit from the tumbled exit of the projectile. The wound leaked for 9 minutes until the pressure was reduced to zero. When repressurized the wound held its seal. Total leakage was 1.2 gallons in 9 minutes.

BLOCK NUMBER B 10

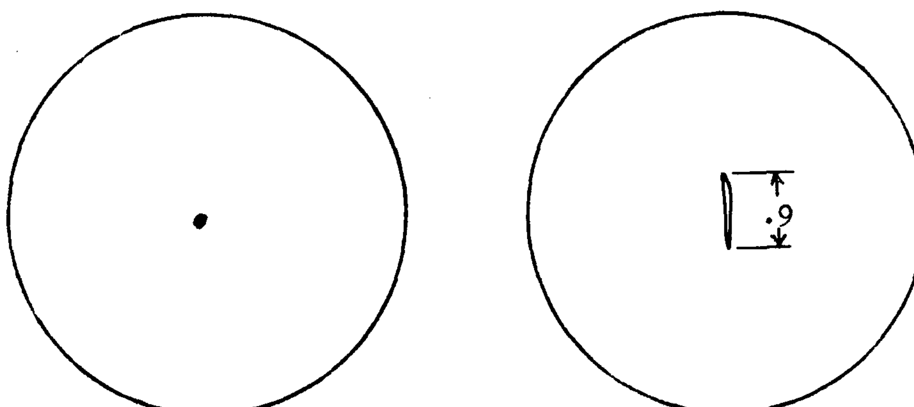
ROUND NUMBER T 14

ENTRANCE | *EXIT



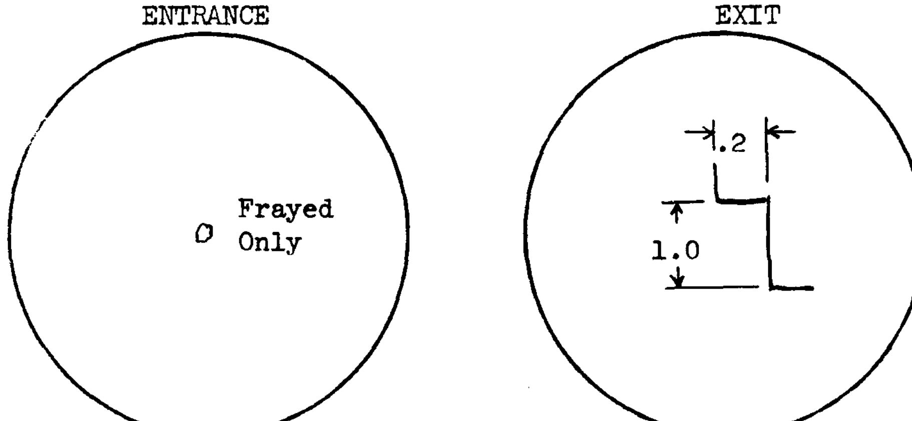
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 10 ROUND NUMBER T 15

DATE FIRED 2 December 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material 7075-T6 (.080) Skin Gap .6 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2600 - 2700 Ft/Sec

MATERIAL:

Backing Board Air Logistics SI EN 2-23 (Cal. 30)

Composite ------------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored No

COMMENTS:

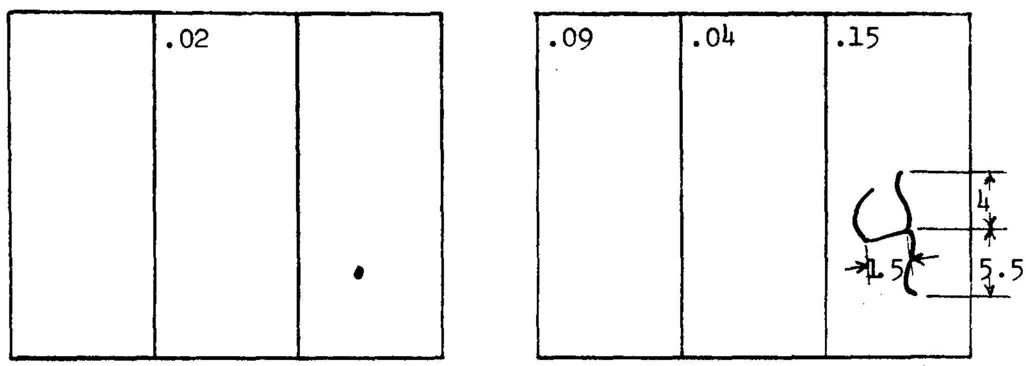
Entrance: The projectile entered straight. The entrance metal was cored but no petaling existed and the backing board was frayed. The self-sealing material sealed. There was no trace of fuel leakage.

Exit: The projectile exited fully tumbled and near zero velocity. The projectile was lying just behind the specimen. The exit metal was torn badly and some coring of the backing board was present. The self-sealing material sealed immediately.

BLOCK NUMBER B 10

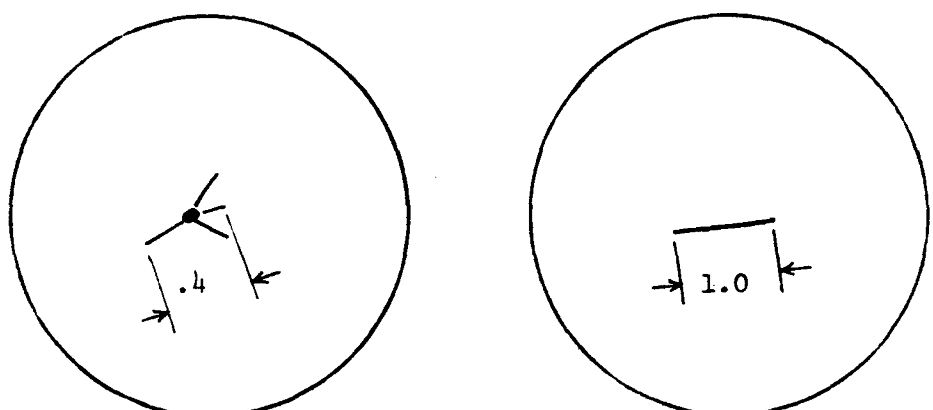
ROUND NUMBER T 15

ENTRANCE *EXIT



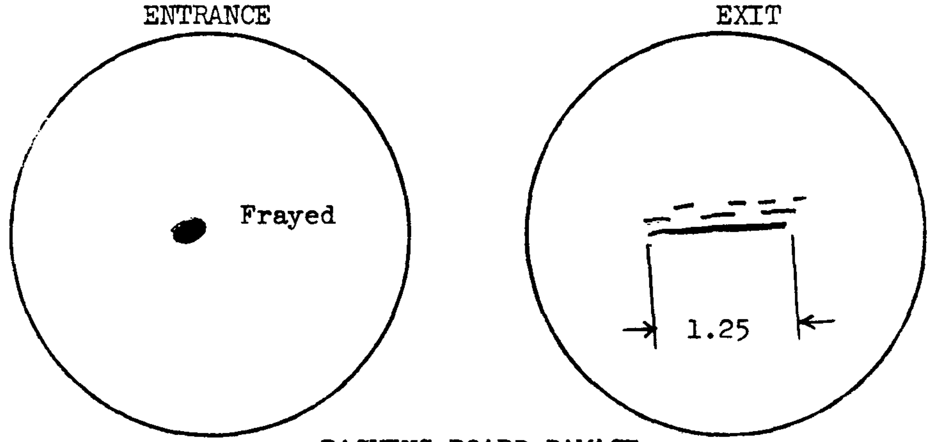
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B10 ROUND NUMBER T16

DATE FIRED 2 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-6 (.080) Skin Gap .6

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity ------------ Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (.30 Cal)

Composite ---------------

Self Sealing Goodyear Tire FTL-11-3 (.50 Cal)

RESULTS:

Entrance Seal Yes Exit Seal No exit

Entrance Cored No Exit Cored N.A.

COMMENTS:

ENTRANCE: FULL TUMBLE

1.5 inches below fuel surface. Skin was cored as was the backing board. The self-sealing material sealed damp immediately. No visable flow of fuel on wound was noted.

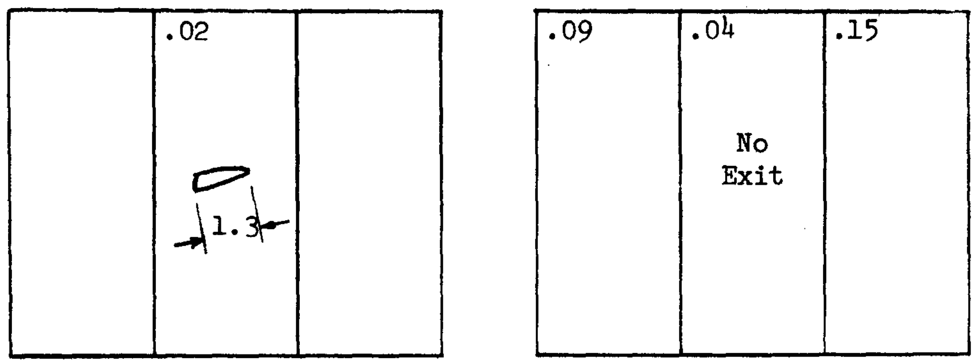
EXIT: NONE

The projectile struck the exit side self-sealing material and just cracked it. No other damage was noted. A flash of fire was seen on the entrance skin.

BLOCK NUMBER B 10

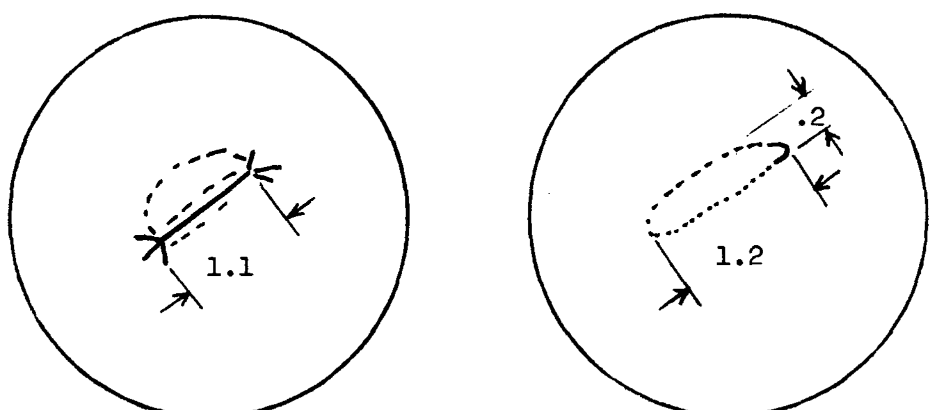
ROUND NUMBER T 16

ENTRANCE | *EXIT



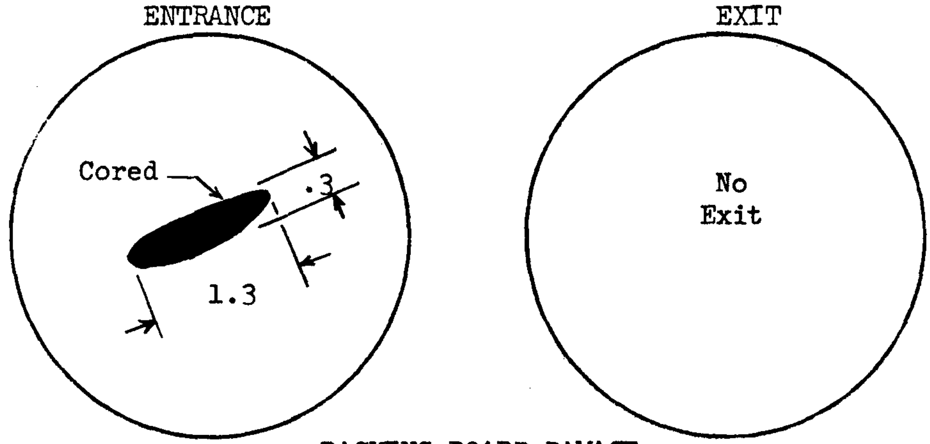
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 10 ROUND NUMBER T 17

DATE FIRED 4 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 (.080) Skin Gap .6 in.

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity 2516 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (.30 Cal)

Composite

Self Sealing Goodyear Tire FTL-11-3 (.50 Cal)

RESULTS:

Entrance Seal Yes Exit Seal Yes

Entrance Cored No Exit Cored no

COMMENTS:

ENTRANCE: 1/3 TUMBLE WITH A BASE FORWARD ENTRY (OVERTUMBLED).

Entrance 4 inches below fuel surface. The skin was cored. The backing board frayed and cored slightly. The self-sealing material was slit and had metal stuck in the wound. However, it sealed around the metal to a damp seal in 4 minutes and dry seal in 10 minutes. No leakage was great enough to measure.

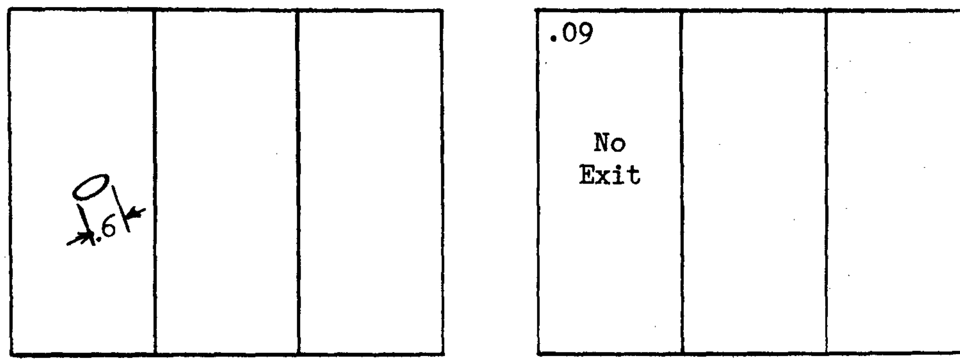
EXIT: NONE

The self-sealing material was partially split but not penetrated by the projectile. No Leakage occurred.

BLOCK NUMBER B 10

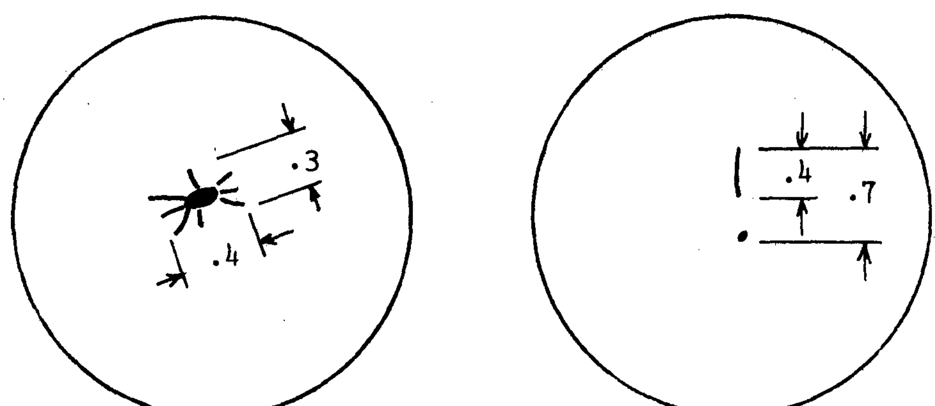
ROUND NUMBER T 17

ENTRANCE *EXIT



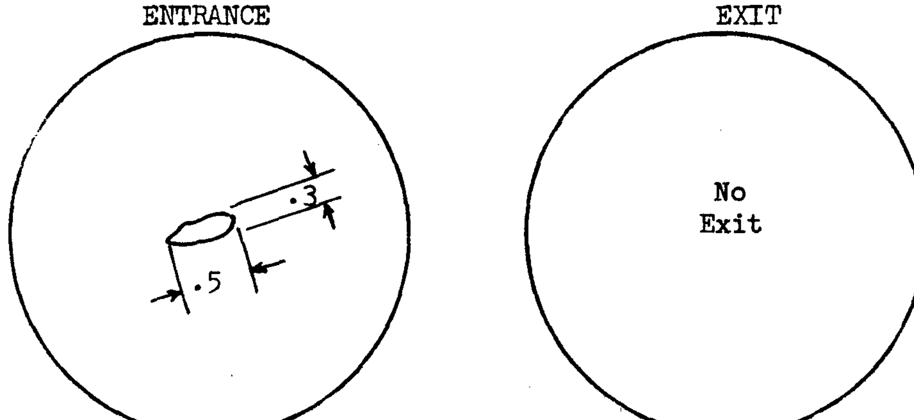
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B10 ROUND NUMBER T18

DATE FIRED 4 December 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material 7075-T6 (.080) Skin Gap .6

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity 2548 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (.30 cal)

Composite

Self Sealing Goodyear Tire FTL-11-3 (.50 Cal)

RESULTS:

Entrance Seal Yes Exit Seal Yes

Entrance Cored Yes Exit Cored No

COMMENTS:

ENTRANCE: 1/3 TUMBLE WITH BASE FORWARD ENTRY (OVERTUMBLED)

Entrance 3.5 inches below the fuel surface. The skin was cored as was the backing board. No trace of any fuel leakage.

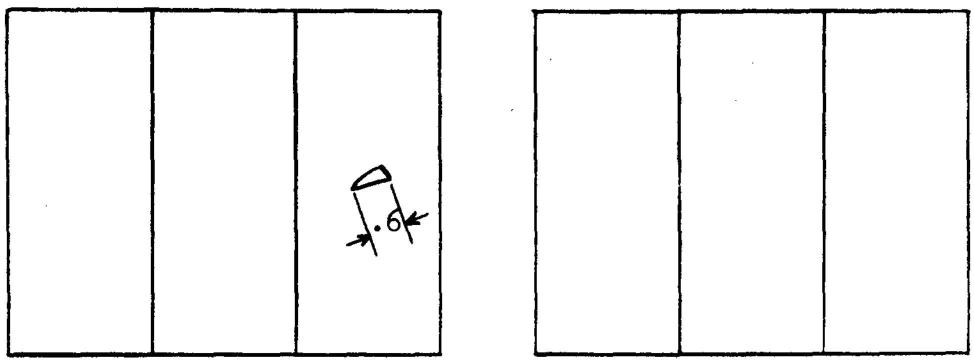
EXIT: NONE.

The projectile slit the back self-sealing material but did not damage the backing board or skin. No leakage.

BLOCK NUMBER B 10

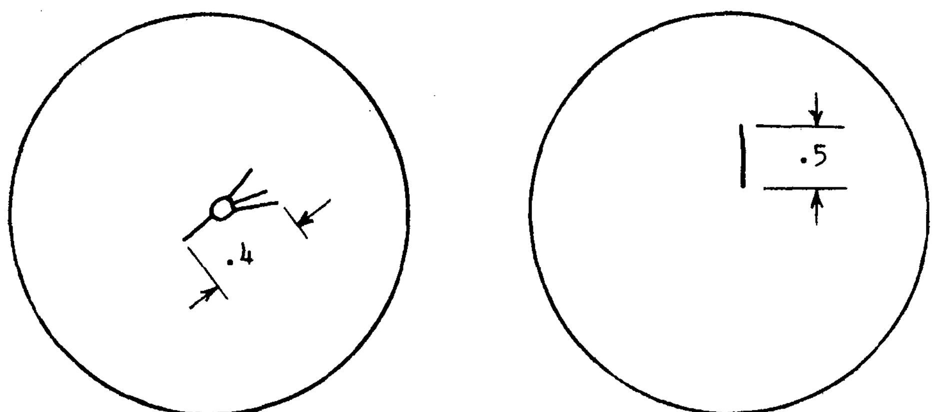
ROUND NUMBER T 18

ENTRANCE *EXIT



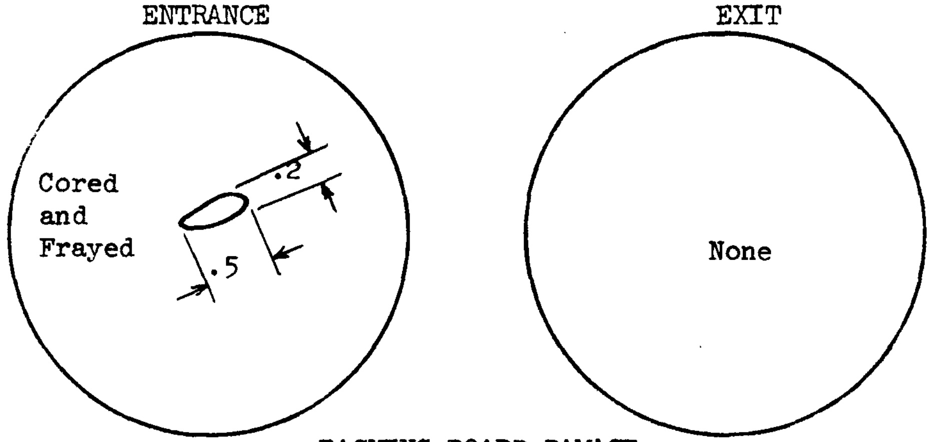
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B9 ROUND NUMBER T19

DATE FIRED 5 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material None Skin Gap No Skin

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2564 Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT 13 IN. BELOW FUEL SURFACE.

Backing board frayed but there was no trace of leakage in the self sealing wound. Instant seal.

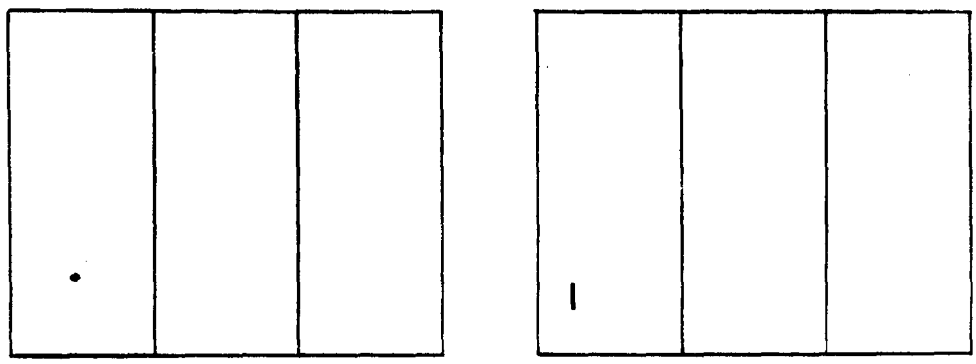
EXIT: 3/4 TO FULL TUMBLE - 14.75 IN BELOW FUEL.

Nicked the wood support. The backing board frayed. The wound flowed fuel for 2 minutes then stalled to a drip. The wound would not seal any more and a constant leakage rate of 100 drops/minute was maintained. When given support the wound would seal to a damp seal with very slow dripping. Had to apply support to wound to continue shots. Did leak some when pressurized (200 drops/minute).

BLOCK NUMBER B 9

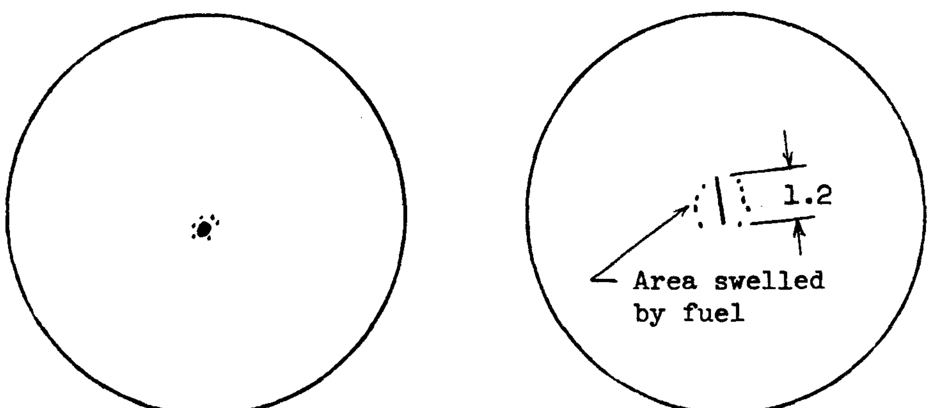
ROUND NUMBER T 19

ENTRANCE NO SKIN *EXIT



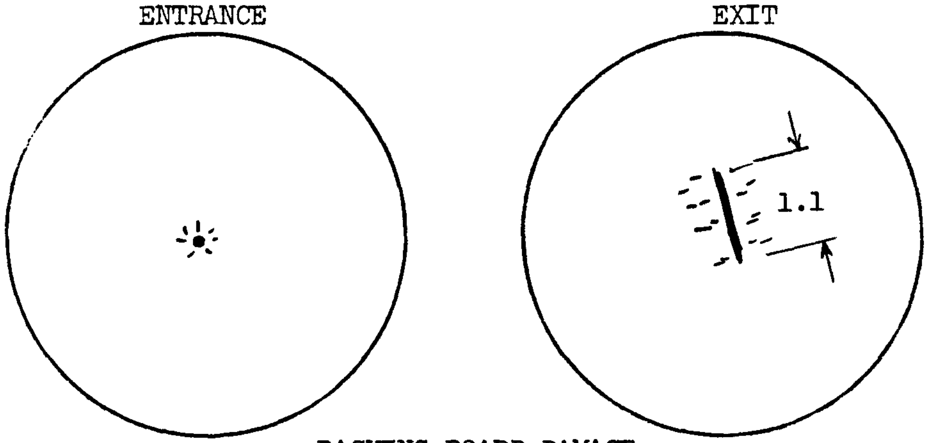
COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B9 ROUND NUMBER T20

DATE FIRED 5 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material None Skin Gap No Skin

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2614 Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT 12.6 INCHES BELOW FUEL SURFACE.

Backing board frayed but the self-sealing material sealed instantly with no trace of fuel leakage.

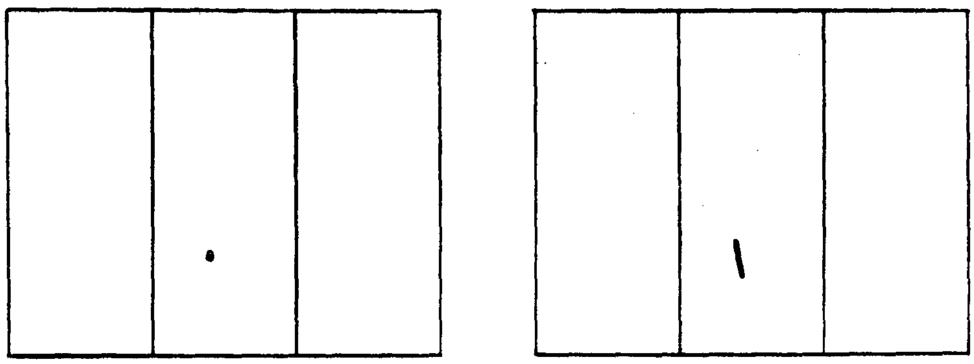
EXIT: FULLY TUMBLED

Backing board frayed and the self-sealing material wound leaked at approx. 1/8 gal/min rate until the pressure was reduced to 0. When repressurized the wound would partially open.

BLOCK NUMBER B 9

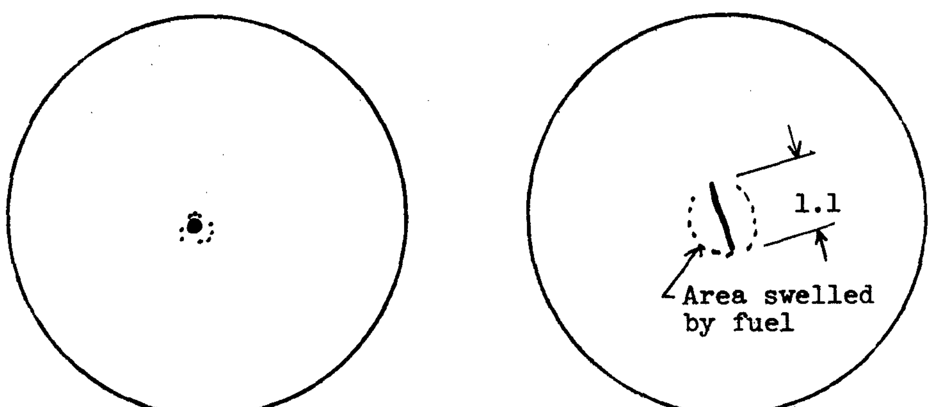
ROUND NUMBER T 20

ENTRANCE   NO SKIN   *EXIT



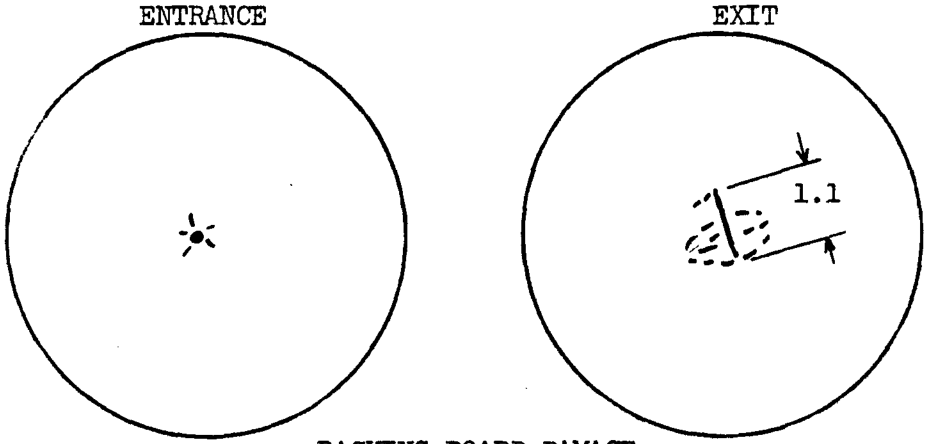
COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE   EXIT



TANK DAMAGE

ENTRANCE   EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B9 ROUND NUMBER T21

DATE FIRED 5 December 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material None Skin Gap No Skin

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity - Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT ENTRY 12 INCHES BELOW FUEL SURFACE

Backing board frayed some. Self-sealing sealed instantly with no trace of fuel leaking.

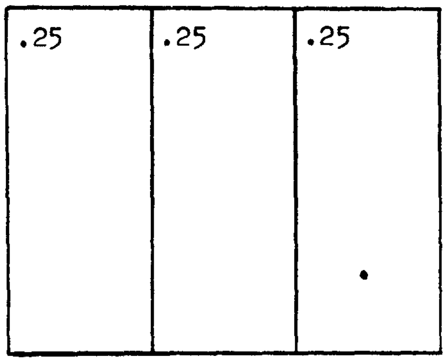
EXIT: FULL TUMBLE 11 INCHES BELOW FUEL SURFACE.

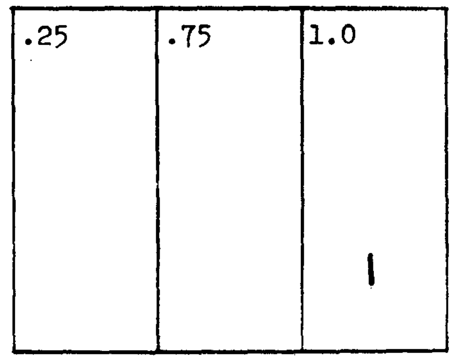
Backing board frayed and self sealing leaked at a rate of 500 ml/min constant until pressure was released.

BLOCK NUMBER B 9

ROUND NUMBER T 21

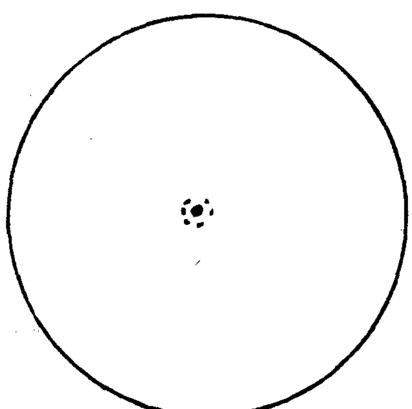
ENTRANCE — NO SKIN — *EXIT



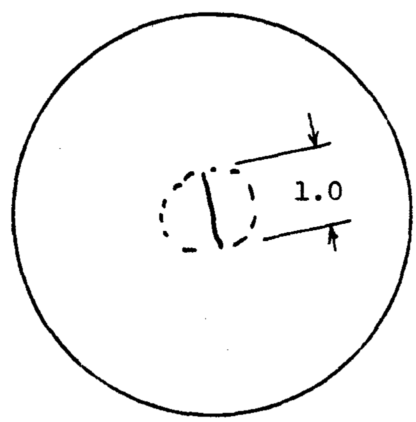


COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

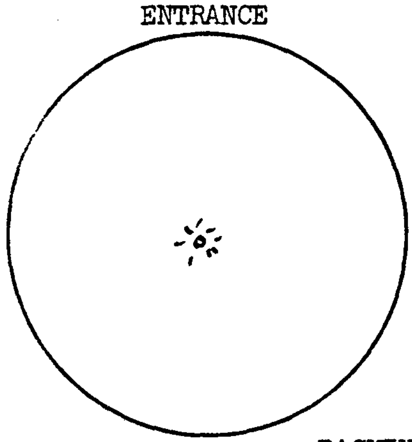


EXIT

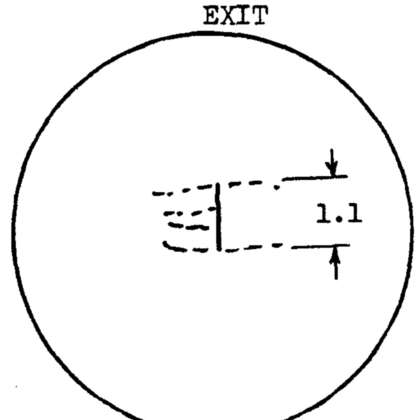


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank

All dimensions are reported in inches.

BLOCK B9 ROUND NUMBER T22

DATE FIRED 5 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material No skin Skin Gap None

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity 2439 Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal No Exit Seal No exit

Entrance Cored Yes Exit Cored N.A.

COMMENTS:

ENTRANCE: 3/4 TUMBLE 2 IN. BELOW FUEL SURFACE.

Backing board frayed and cored. Sealing material cored slightly. No seal affected. Leaked at Constant Rate of 100/ml per minute at 0 pressure. FAILURE.

EXIT: NONE

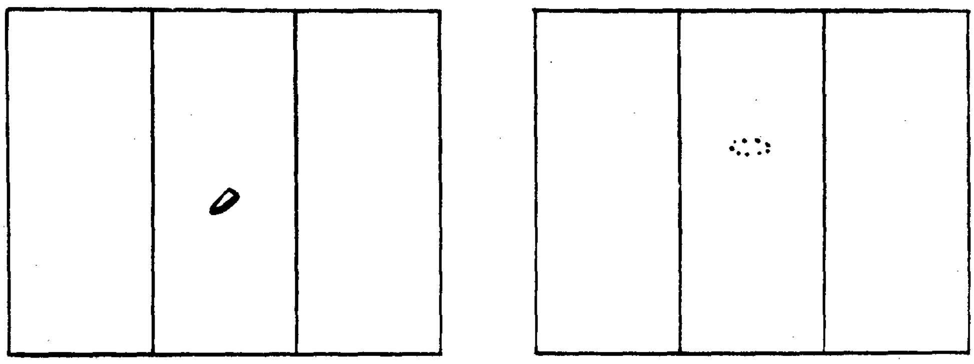
Note: The Projectile lost its nose before hitting the entrance. The nose hit the jig and splattered thus causing other damage to the entrance side with one penetration from shrapnel. Wound sealed though.

On disassembly the self sealing material was found to be cracked where it was impacted by the projectile.

BLOCK NUMBER B 9

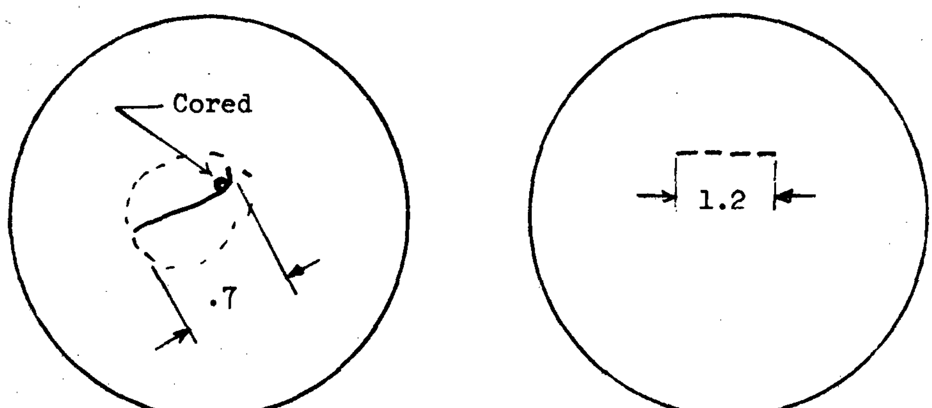
ROUND NUMBER T 22

ENTRANCE *EXIT



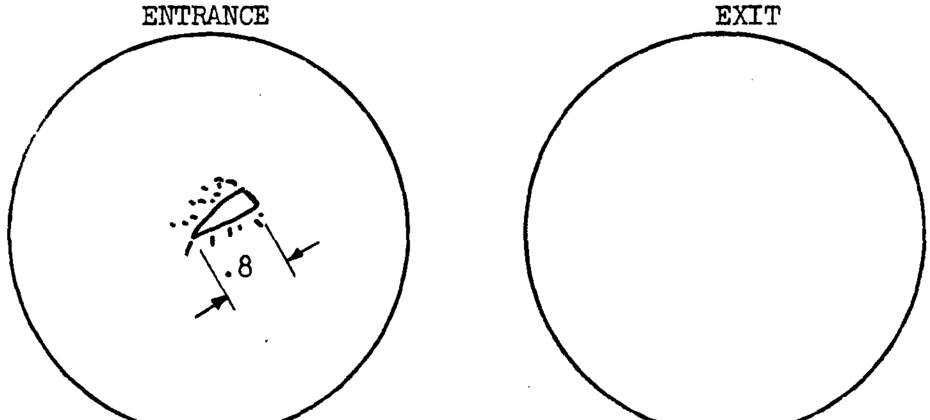
COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B1 ROUND NUMBER T23

DATE FIRED 6 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.080 in.) Skin Gap 1.25 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2632 Ft/Sec

MATERIAL:

Backing Board Gillfab 1068 (.025 in.)

Composite ----------------------

Self Sealing Uniroyal US 179 (Cal .30)

RESULTS:

Entrance Seal Yes Exit Seal After 5 minutes 0 pressure

Entrance Cored No Exit Cored No

COMMENTS:

The projectile entered straight and exited 3/4 to fully tumbled coring the skin on both entrance and exit. The backing board on the entrance side was cored and splattered from coring of the skin but stopped most of it

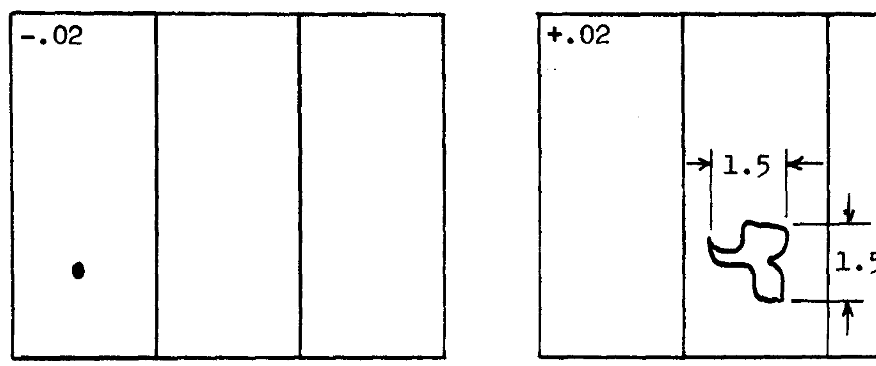
The sealant material was not damaged on the entrance, but on the exit it was slit .8 inches long and required 5 minutes to obtain a full seal. Total leakage was 100 ml. However, when pressurized to 2 PSIG the wound opened and continued to leak at a rate of approximately 100 ml/minutes.

NOTE: The deflection on the entrance of skin was inward toward fuel.

BLOCK NUMBER B 1

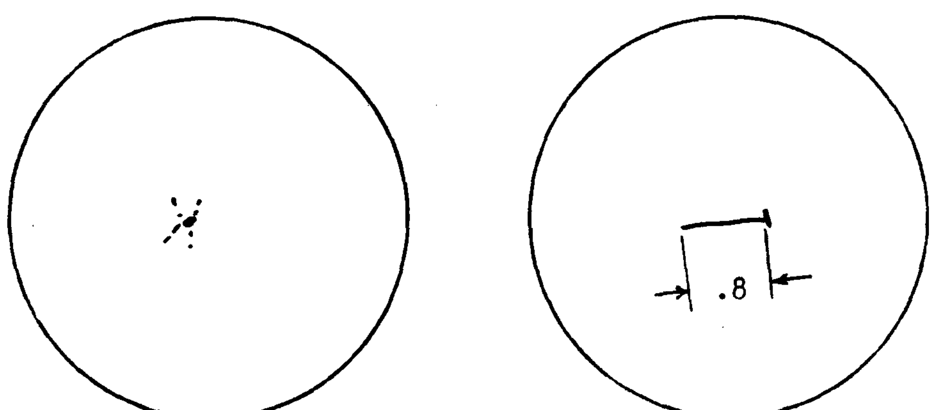
ROUND NUMBER T 23

ENTRANCE *EXIT



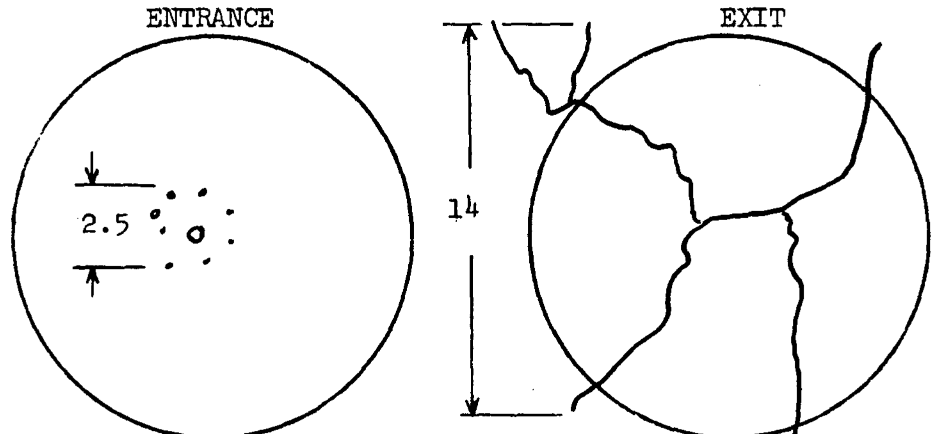
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B1 ROUND NUMBER T24

DATE FIRED 6 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 Bore (.080 in.) Skin Gap 1.25 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2614 Ft/Sec

MATERIAL:

Backing Board Gillfab 1068 (.025 in.)

Composite --------------------

Self Sealing Uniroyal US 179 (Cal .30)

RESULTS:

Entrance Seal Yes

Entrance Cored No

Exit Seal No: Rate 1.6 gal/min after 2 minutes

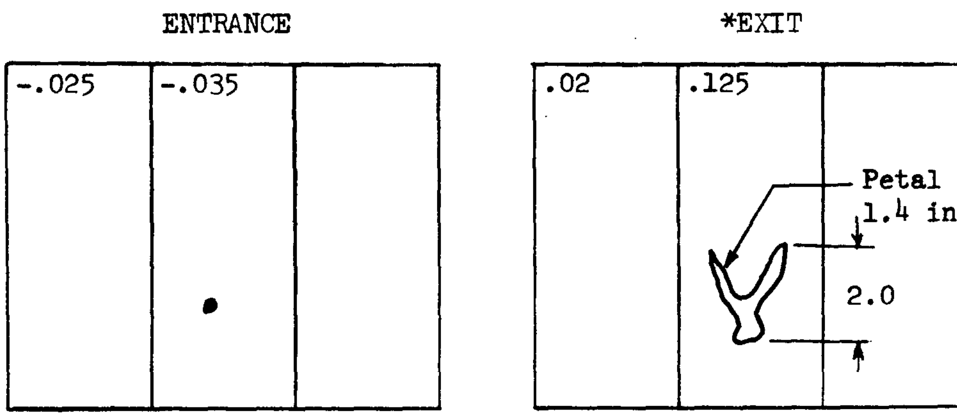
Exit Cored No

COMMENTS:

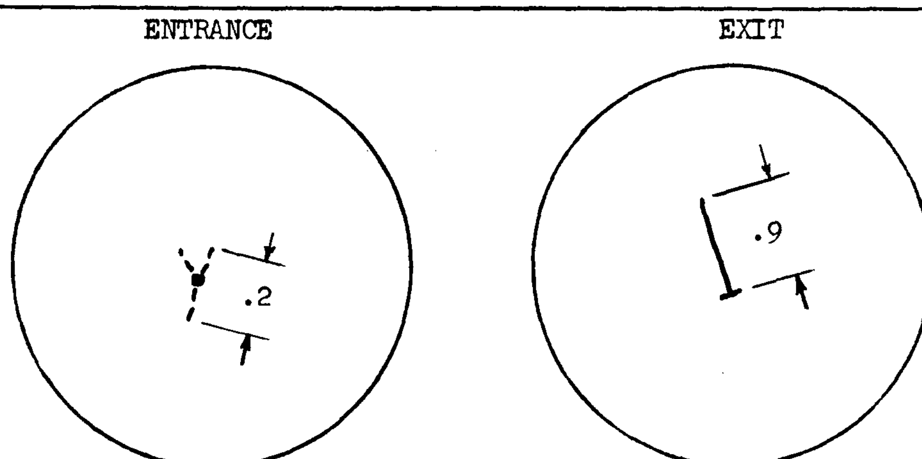
The projectile entered straight but exited 3/4 to full tumbled. The skin cored both entrance and exit. Backing board was cored on entrance and splattered with shrapnel from skin. The exit backing board was destroyed giving no support at all to the self-sealing material. The self-sealing material suffered little damage on the entrance with a good seal. The exit did not seal with 2 psig pressure or with 0 pressure. It is thought to be because of lack of support between it and the skin because no coring was evident. Upon inspection, the sealant material was found against the exit skin. A hole shows evidence of trying to seal off the leakage.

BLOCK NUMBER B 1

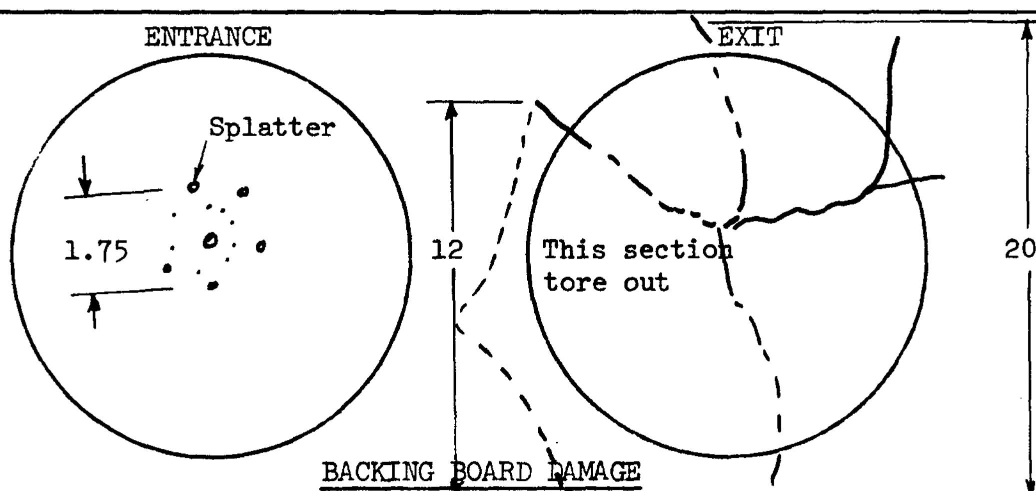
ROUND NUMBER T 24



SKIN PANEL DAMAGE AND DEFLECTIONS



TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B5 ROUND NUMBER T25

DATE FIRED 7 December 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.040 in) Skin Gap 1.0 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2632 Ft/Sec

MATERIAL:

Backing Board Gillfab 1075 (.025 in)

Composite ---------------------

Self Sealing Goodyear Tire FTL-13 (Cal .30)

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored Yes (BB)

COMMENTS:

The projectile entered straight and exited fully tumbled. The entrance of the skin was petaled with little coring while the exit was petaled and cored.

The entrance backing board was cored .3 diameter but the exit board was totally failed--torn from top to bottom and cored at the projectile impact point.

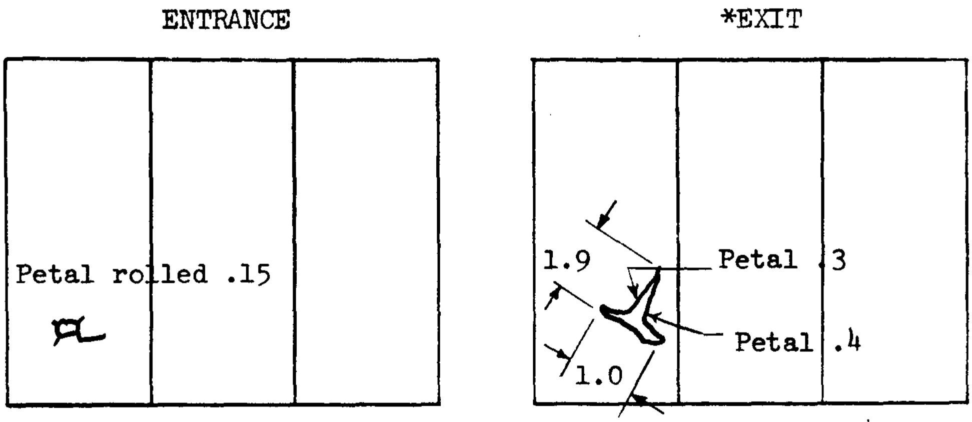
The self-sealing material suffered little damage on the entrance but was cut 1.10 inches long on the exit. The back side (away from the fuel) was frayed some and did not seal.

The main reason for no seal was because the support was lost from the backing board.

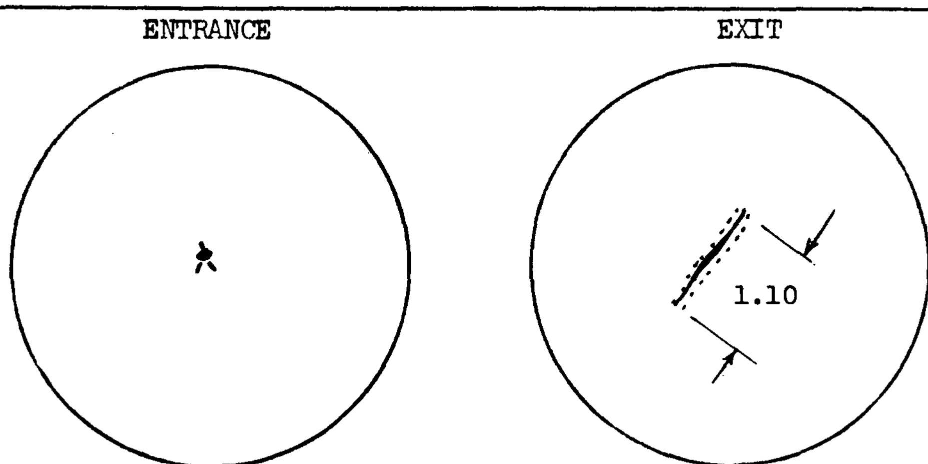
Leakage rate was approximately 3 gal/min constant.

BLOCK NUMBER B 5

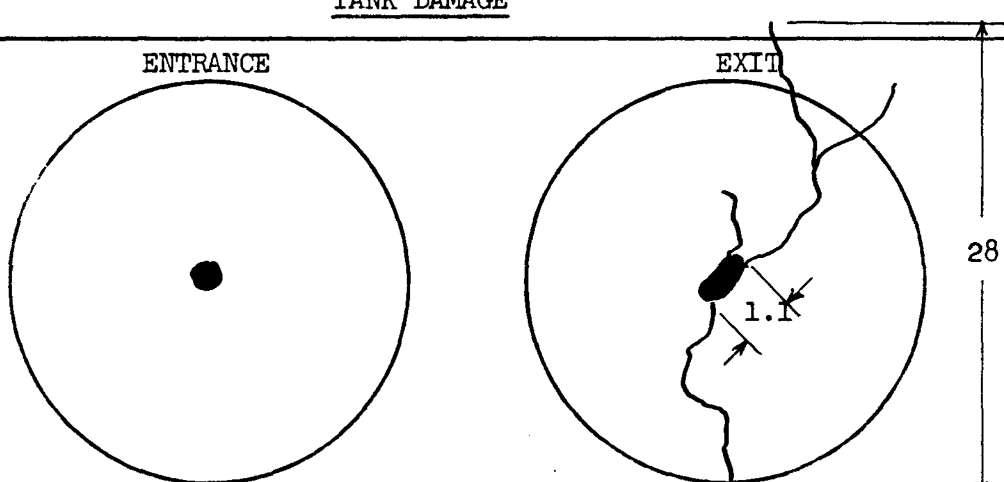
ROUND NUMBER T 25



SKIN PANEL DAMAGE AND DEFLECTIONS



TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B3 ROUND NUMBER T26

DATE FIRED 8 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080 in.) Skin Gap 1.0 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2685 Ft/Sec

MATERIAL:

Backing Board Gillfab 1068 (.025 in.)

Composite ----------------------

Self Sealing Firestone 1316-3 (Cal .30)

RESULTS:

Entrance Seal Yes Exit Seal No

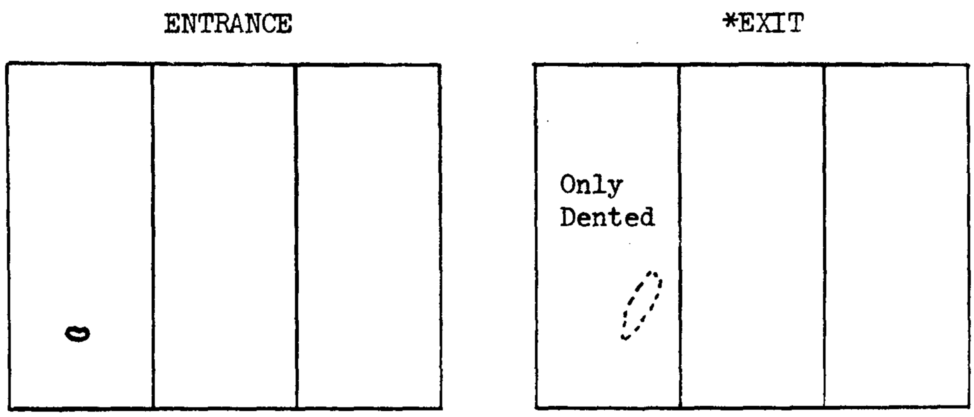
Entrance Cored No Exit Cored No

COMMENTS:

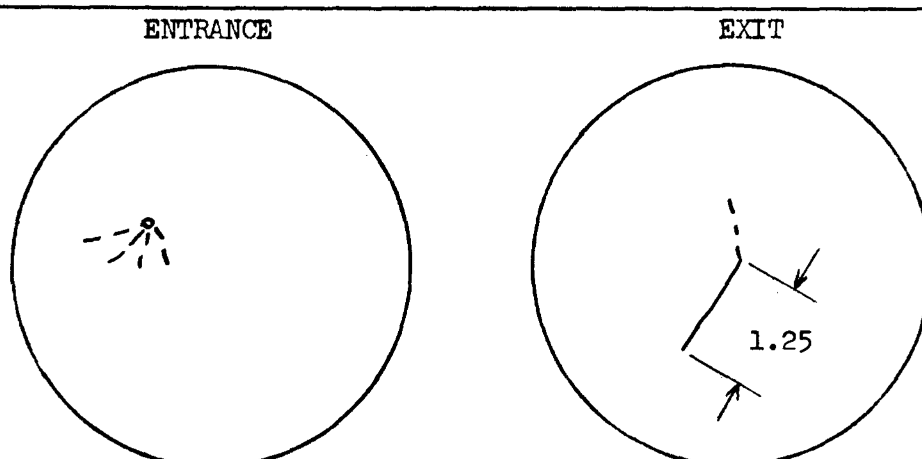
The projectile entered straight, coring the skin and creating a .2 in. high petal and fraying the backing board. The self-sealing material leaked enough to wet the surface but did not drip any. The wound on the entrance was cracked some but no coring was present. The projectile exit was fully tumbled. The projectile did not puncture the skin but did dent it. The backing board was split out giving no support to the sealing material. The sealing material suffered a 1.25 inch split with cracking. The self sealant was not activated thus no seal was obtained. The leakage rate was 1.2 to 1.35 gal/min constant rate.

BLOCK NUMBER B 3

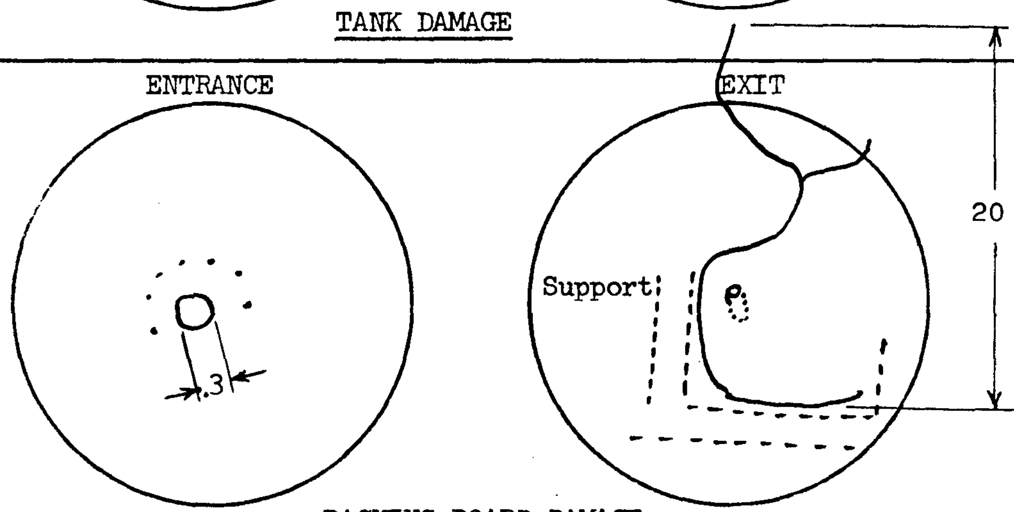
ROUND NUMBER T 26



SKIN PANEL DAMAGE AND DEFLECTIONS



TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B6 ROUND NUMBER T27

DATE FIRED 9 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080 in.) Skin Gap .75 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2632 Ft/Sec

MATERIAL:

Backing Board Gillfab 1075 (.030)

Composite ------------------

Self Sealing Uniroyal US 180 (Cal .30)

RESULTS:

Entrance Seal Yes Exit Seal Yes

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT WITH SLIGHT TUMBLE

The skin was cored and petaled to a .2 in. height. The Backing Board was frayed and cored the size of the projectile. Self-sealing material seeped some but was not measurable. Dry surface wound in 2 minutes.

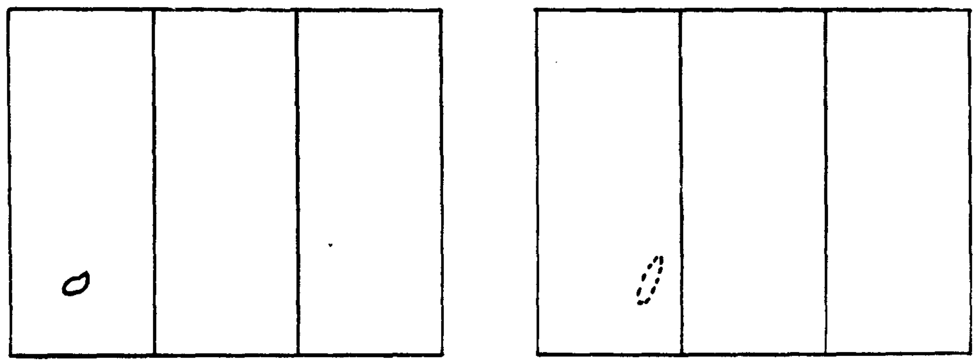
EXIT: TUBMLE

The skin was not penetrated but was dented size of tumbled round. The backing board was split to total failure - no support. Self-sealing material seeped but no drips occurred until pressurized. At 2 psi pressure the leakage rate was constant at 96 drops/minute. At 0 pressure the wound would dry up to a dry seal.

BLOCK NUMBER B 6

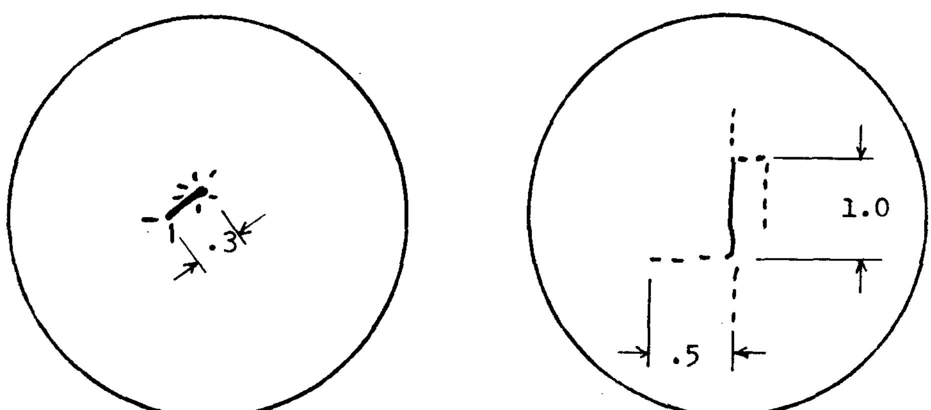
ROUND NUMBER T 27

ENTRANCE | *EXIT



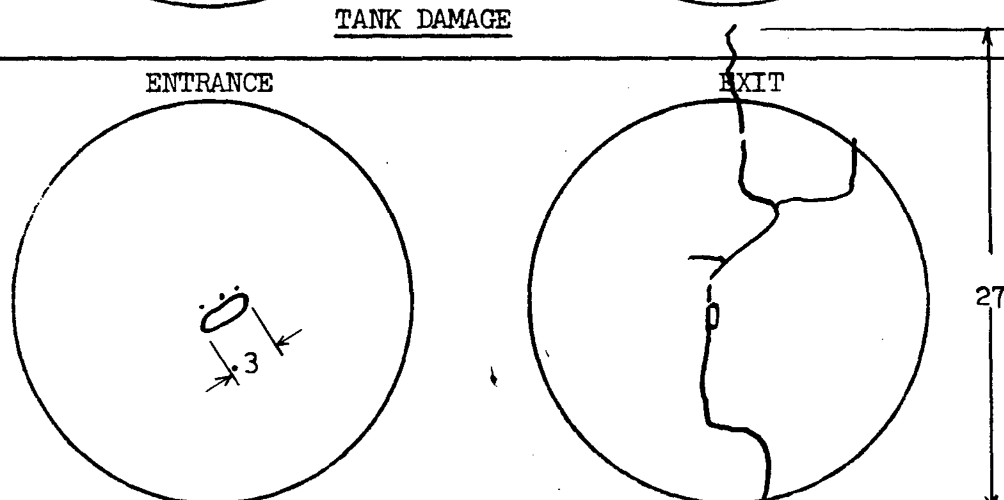
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B6 ROUND NUMBER T28

DATE FIRED 9 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.080 in) Skin Gap .75 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2614 Ft/Sec

MATERIAL:

Backing Board Gillfab 1075 (.030 in.)

Composite --------------------

Self Sealing Uniroyal US 180 (Cal. 30)

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored No

COMMENTS:

ENTRANCE: STRAIGHT

There was no deflection of skin. The skin was cored and petaled .2 inches high. The backing board was cored and frayed size of projectile diameter. The self-sealing material sealed instantly with no trace of fuel.

EXIT: FULLY TUMBLED

The skin cored and petaled to a height of 1.6 inches. Backing board failed completely giving no support to the sealing material.

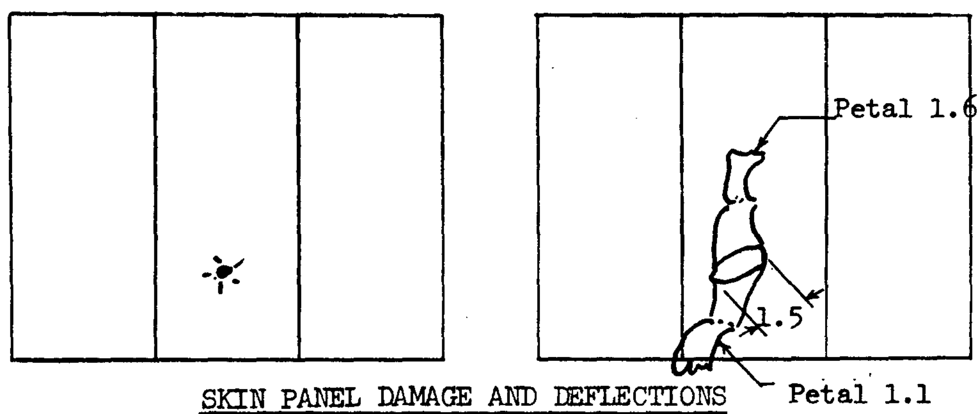
The self-sealing material did not seal at all due to no support and the self sealant did not seem to be activated very much.

Self-sealing material was against skin after the shot. Leakage only slowed with a reduction in pressure. Rate was approximately 2 to 2.5 gal/min.

BLOCK NUMBER B 6

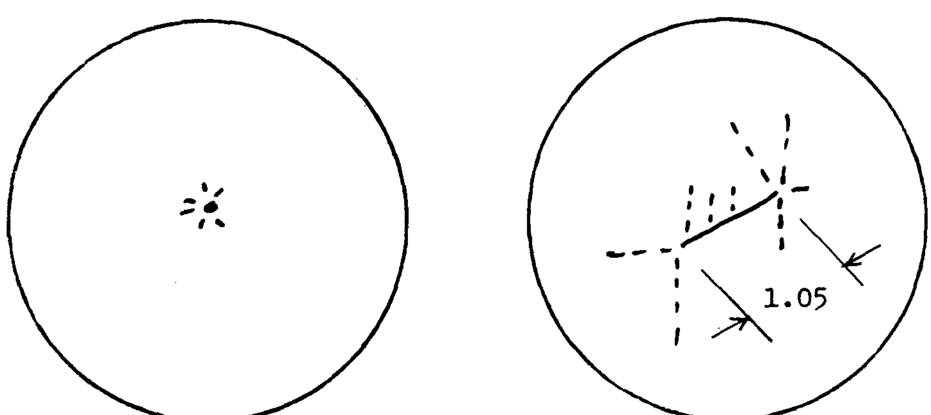
ROUND NUMBER T 28

ENTRANCE *EXIT



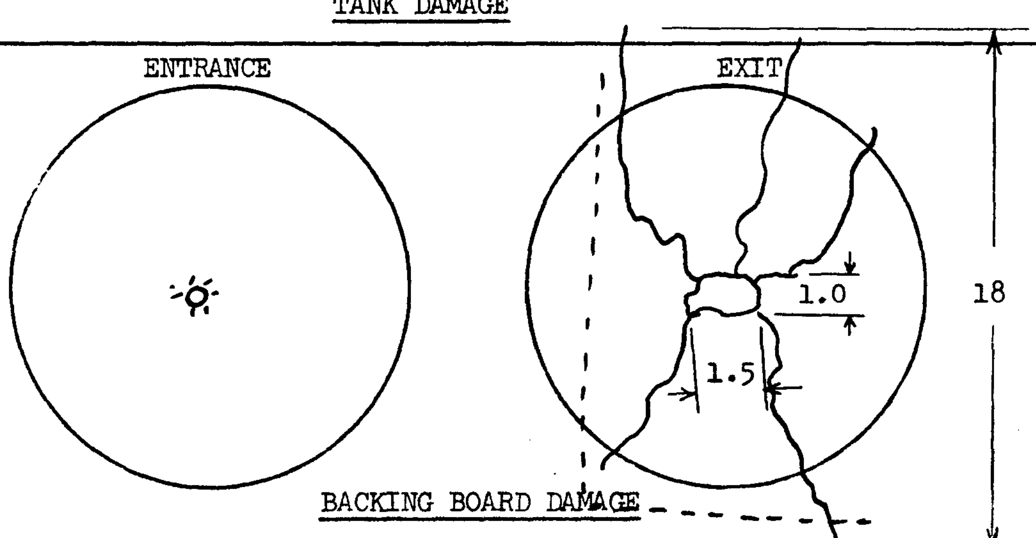
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B20 ROUND NUMBER T29

DATE FIRED 9 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling Orange Foam

Skin Material 6061-6T Bare (040 in.) Skin Gap 1.00

PROJECTILE:

Caliber .50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board Airlogistics 700 SI - EN2-23

Composite ----------------------

Self Sealing Uniroyal US-180 (Cal. 30)

RESULTS:

Entrance Seal Yes Exit Seal No

Entrance Cored No Exit Cored No

COMMENTS:

Saw large flash as round struck entrance panel.

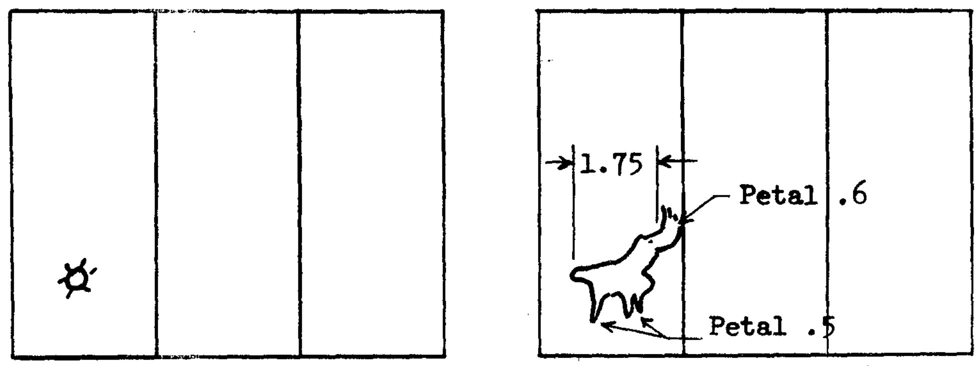
The projectile entered straight, coring and petaling the skin. The backing board was also cored but the self-sealing material held with no visible leakage. The exit wound was from the projectile being fully tumbled. The skin was petaled and cored. The backing board was frayed such that no support was left for the self-sealing material wound. The self-sealing material suffered a slit with cracking. No support was available so the wound leaked at a rate of 175 ml/min (0 press) constant. When given support with the edge of a 6-inch scale the wound would seal to a drip rate. When pressurized the wound would flow full force.

The 2-inch vent was open on the tank. No fuel escaped the vent.

BLOCK NUMBER B 20

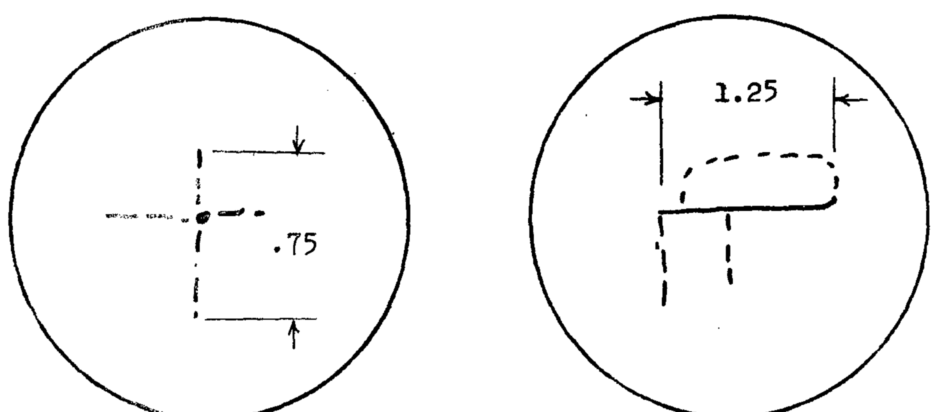
ROUND NUMBER T 29

ENTRANCE *EXIT



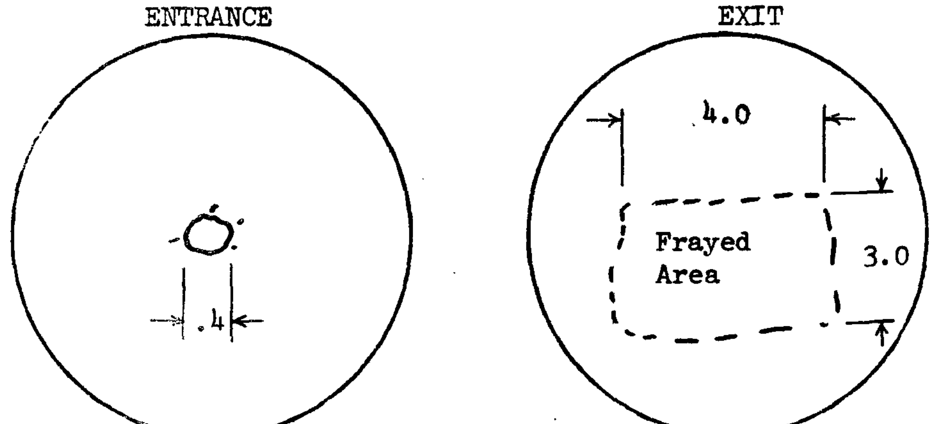
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 20 ROUND NUMBER T 30

DATE FIRED 9 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling Orange foam

Skin Material 6061-T6 Bare (.040) Skin Gap 1 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity ------------ Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23

Composite ----------------

Self Sealing Uniroyal US-180 (Cal. 30)

RESULTS:

Entrance Seal no Exit Seal no

Entrance Cored No Exit Cored no

COMMENTS:

Entrance: Fully tumbled.

The skin and backing board were cored. The self-sealing material looked like it did not seal. The entrance caught fire upon impact. The lower clamps on the end frame then failed and fuel started escaping, thus the whole specimen was soon covered with fire. The self-sealing material was pulled into the box so sealing at the lower edge was impossible.

Exit: Fully tumbled.

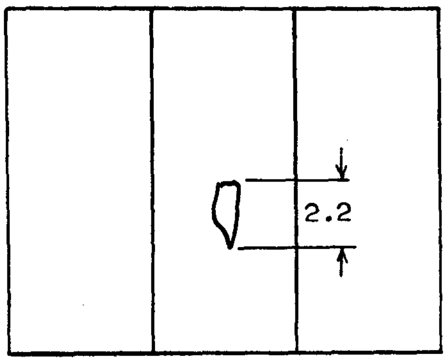
Cored skin and high petaling was evident. There were no measurements because of fire. On disassembly, the self-sealing material suffered a blister from burning approximately 4 inches wide and 8 inches high. Looked as if some leakage occurred at the exit wound also.

The foam in the box was burned at the vent and manometer connections. (2 inch pipes) The vent was open and the foam was burned 2 inches diameter 2 inches deep. At the manometer connection it was burned approximately the same but the foam was still intact. Also, the foam was charred on one side where the box was the hottest. The fire department arrived on the scene and had the fire put out in 6 minutes after the gun was fired.

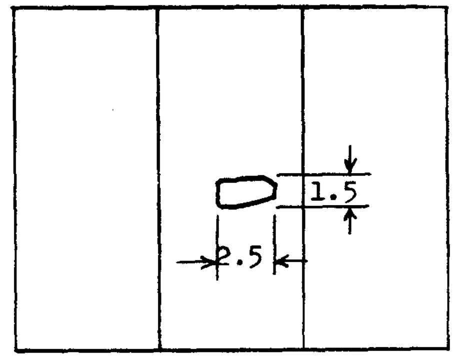
BLOCK NUMBER B 20

ROUND NUMBER T 30

ENTRANCE

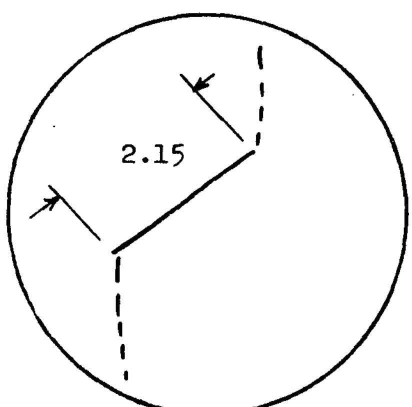


*EXIT

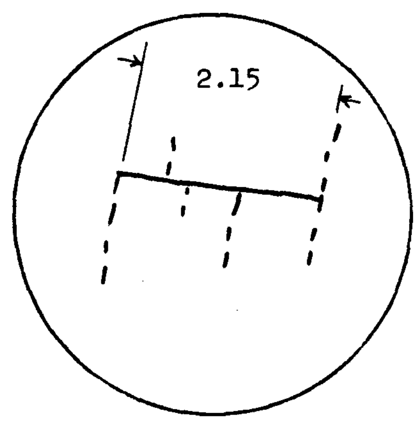


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

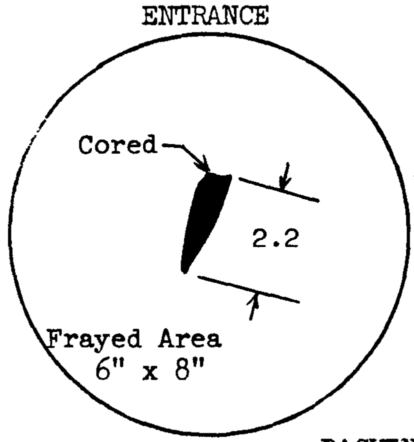


EXIT

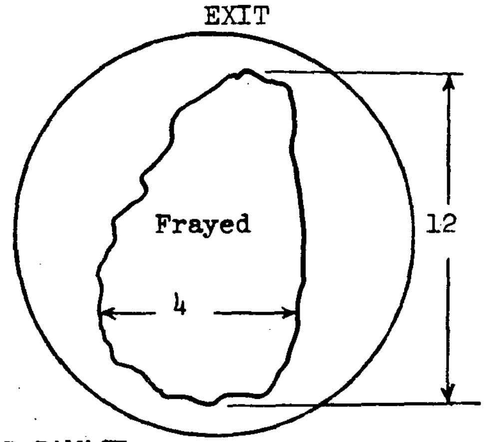


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 25 ROUND NUMBER T 31

DATE FIRED 12 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap 1 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2640 Ft/Sec

MATERIAL:

Backing Board Gillfab 1068 (.025)

Composite ----------------

Self Sealing Goodyear Tire & Rubber FTL-13 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored No Exit Cored no

COMMENTS:

Entrance: Straight

The skin was cored and had .2 inches high petals. The backing board stopped all coring and cored itself the size of the projectile. The self-sealing material was just punctured with no trace of any leakage. The self-sealant was activated.

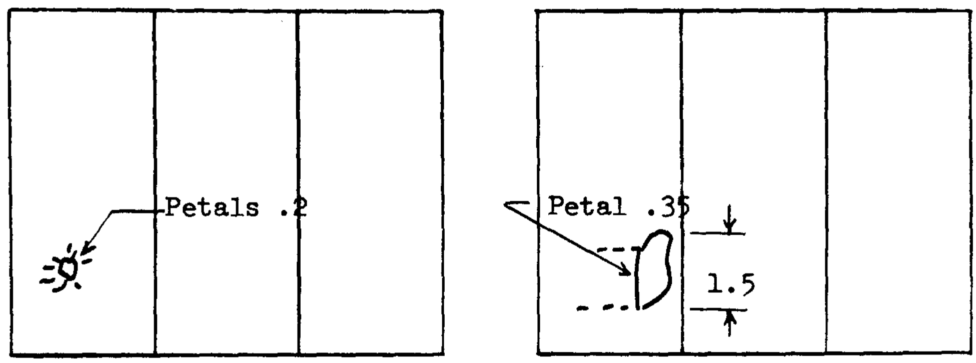
Exit: Full tumble.

The skin was cored and petaled .35 inches high. The backing board was split from top to bottom except for 2 inches at the top, thus giving no support to self-sealing material at all. The self-sealing material was slit but not cored. It did not seal. Leakage rate was .75 gallon/minute at zero pressure and was constant.

BLOCK NUMBER B 25

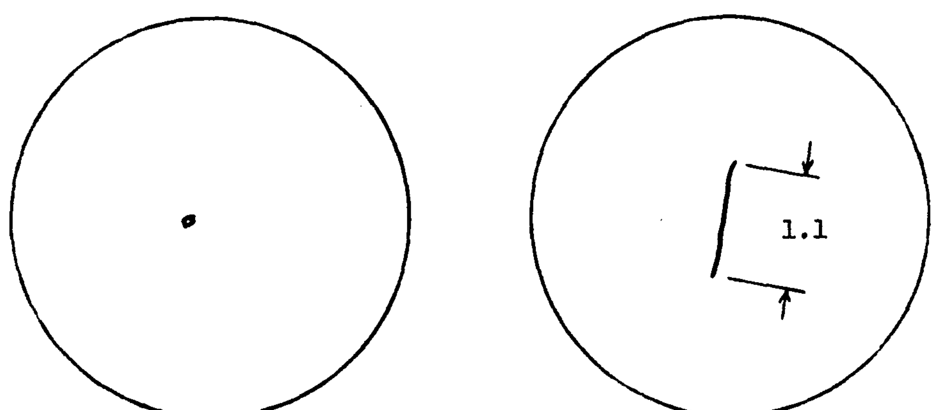
ROUND NUMBER T 31

ENTRANCE *EXIT



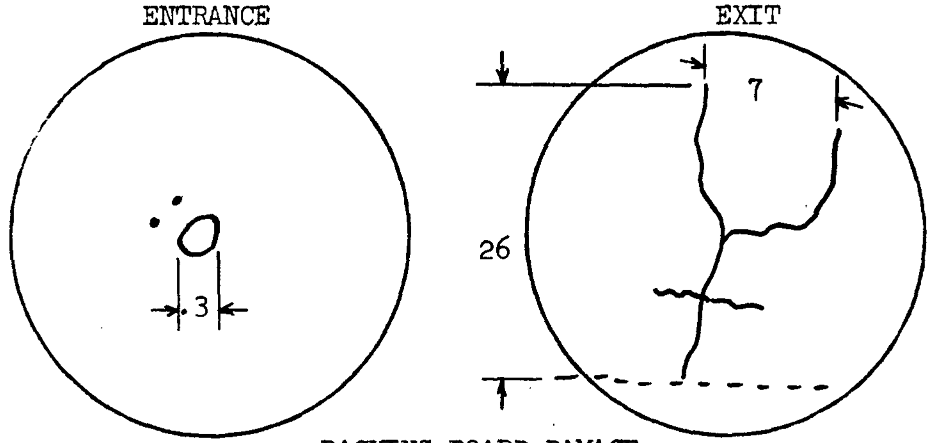
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 48 ROUND NUMBER T 32

DATE FIRED 13 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Exit: 6061-T6 Bare (.040) Skin Gap 1.25 in. exit side only

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2614 Ft/Sec

MATERIAL:

Backing Board Exit: Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite Entrance: Air Logistics 114509-304

Self Sealing Exit: Goodyear Tire DX 325 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

The backing board was just pierced as was the self-sealing material. The skin cored some. The round hit in the plane area of skin. The wound sealed dry immediately. There was no trace of fuel leakage.

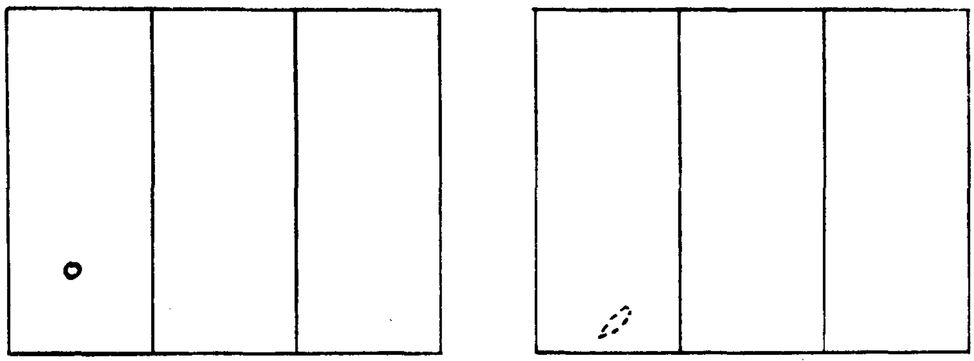
Exit:

No exit occurred through the skin. The round hit low next to the flange. The round lodged in the wound and next to the skin. After moving the projectile with a scale the leakage slowed to a 92 drop/minute from approximately .06 gallon/minute rate. Later after pressurized to 1 psi, the wound did not leak. The skin was just dented. The backing board frayed the size of tumbled round. The self-sealing material was cut but not cored.

BLOCK NUMBER B 48

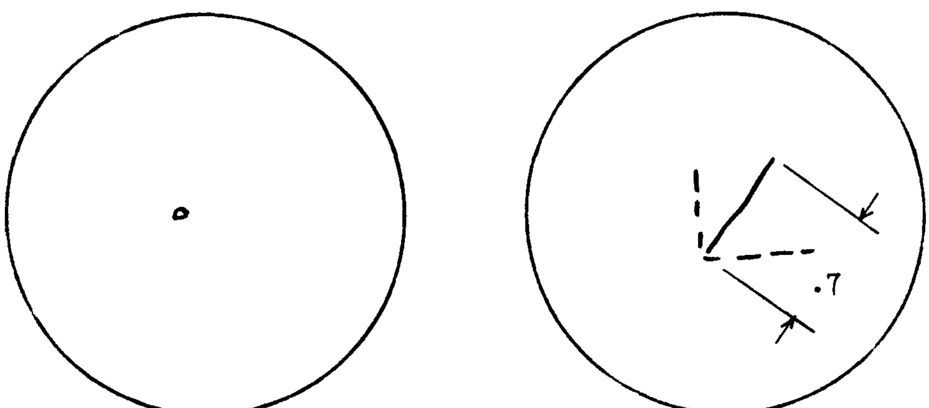
ROUND NUMBER T 32

ENTRANCE *EXIT



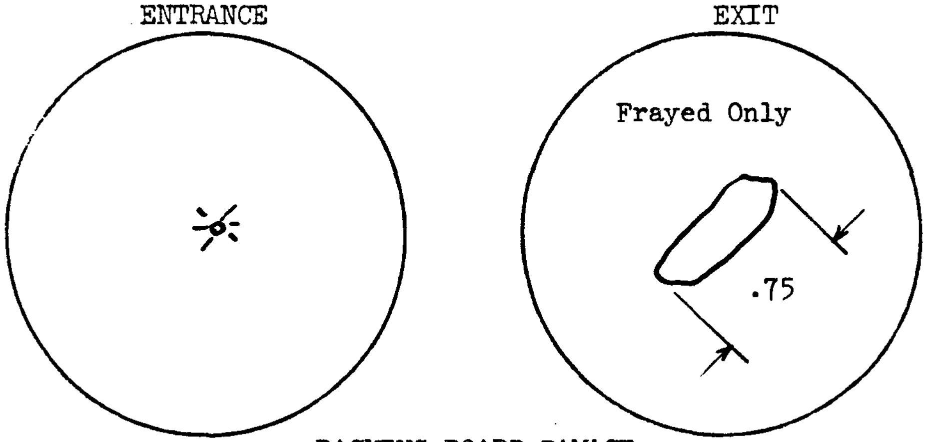
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B48 ROUND NUMBER T33

DATE FIRED 13 Dec. 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Exit 6061-T6 Skin Gap 1.25

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2685 Ft/Sec

MATERIAL:

Backing Board Exit: Air Logistics 700 SI EN2-41 (Cal. 50)

Composite Entrance: Air Logistics 114509-304

Self Sealing Exit: Goodyear Tire DX-375 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: 10.5 in. below fuel level straight.

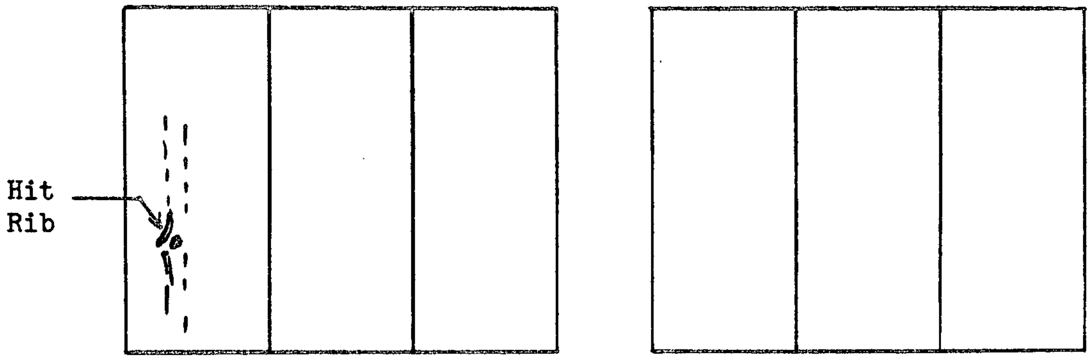
Projectile struck rib in panel coring it. The self-sealing material sealed with no trace of fuel leakage. Backing board frayed some.

Exit: None

Projectile struck back self-sealing material and marked it but did not cut it. No leakage occurred.

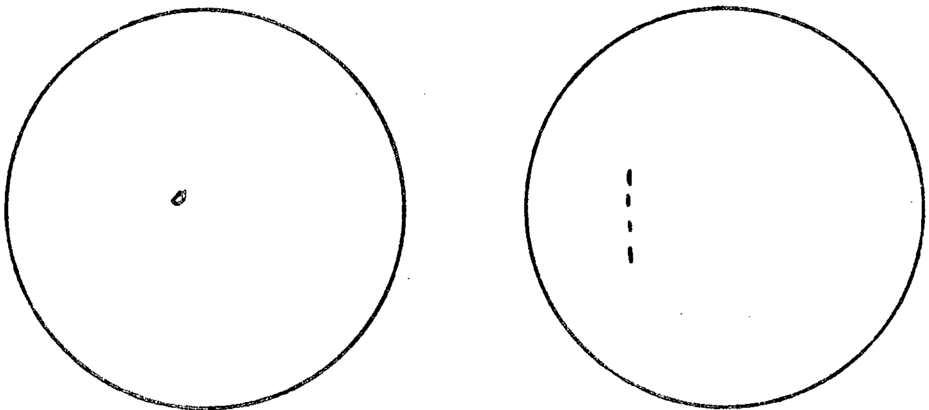
BLOCK NUMBER B 48
ROUND NUMBER T 33

ENTRANCE *EXIT



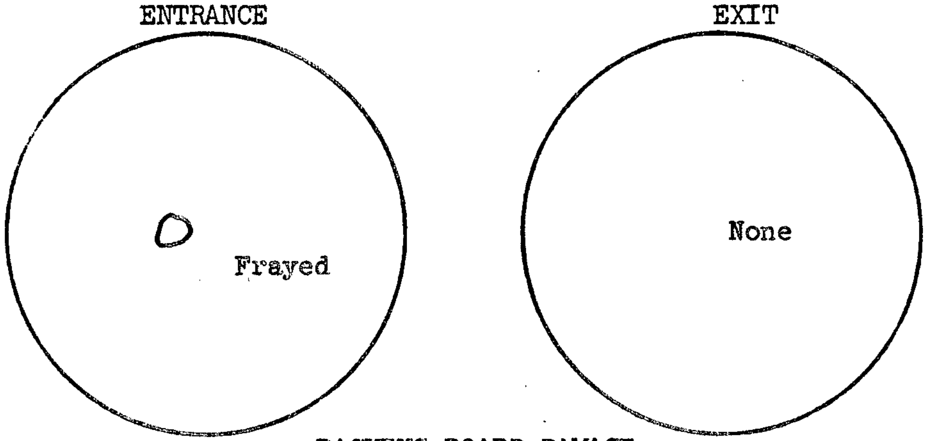
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 48 ROUND NUMBER T 34

DATE FIRED 13 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Exit: 6061-T6 Bare (.040) Skin Gap 1.25 in. exit side only
0 in. front side

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity ---------- Ft/Sec

MATERIAL:

Backing Board Exit: Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite Entrance: Air Logistics 114509-304

Self Sealing Exit: Goodyear Tire DX 325 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: Tumble 2.25 inches below fuel level.

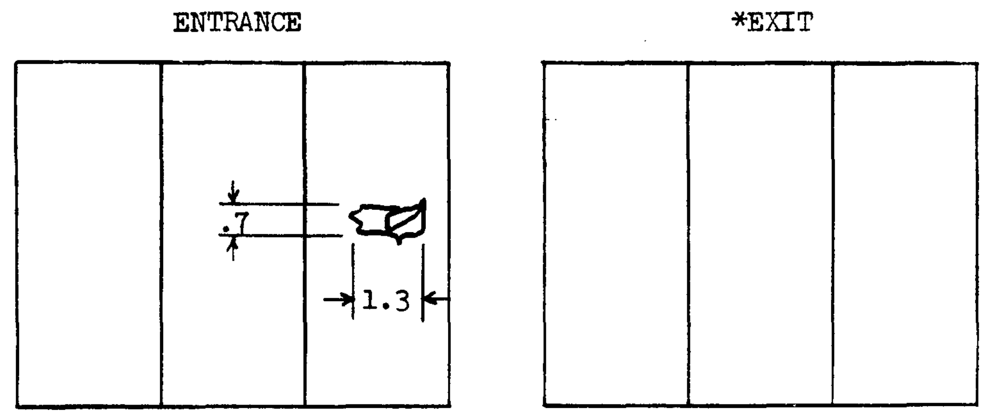
The projectile was aimed at a rib but missed it. The backing board was cored the size of the projectile and frayed considerably. The self-sealing material was only slit, and sealed dry. The skin was cored 1.3 in. x .7 in.

Exit: None

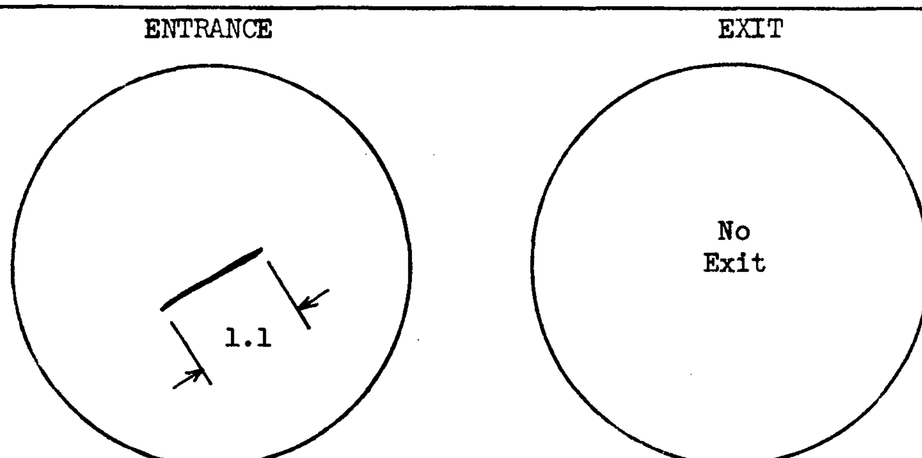
No leakage occurred. After the shot the box was pressurized to 1 psi. No leaks occurred at any of the wounds.

BLOCK NUMBER B 48

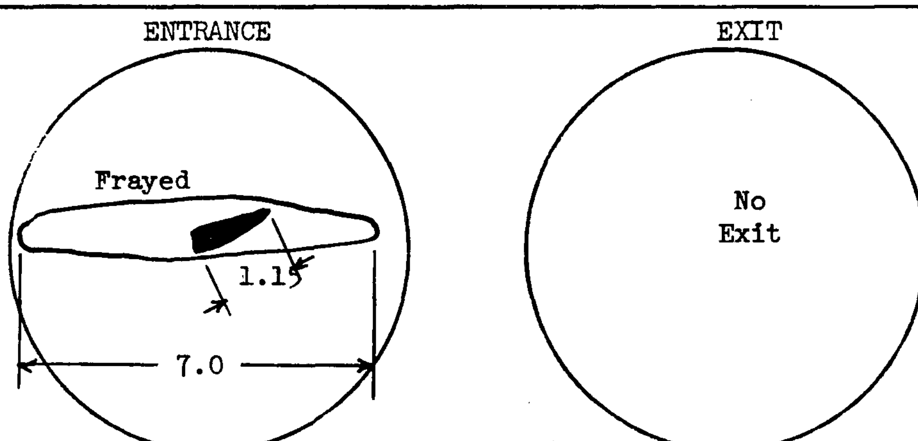
ROUND NUMBER T 34



SKIN PANEL DAMAGE AND DEFLECTIONS



TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 48.1 ROUND NUMBER T 35

DATE FIRED 13 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Exit: 2024-T3 Clad (.080) Skin Gap 1.25 in. (Exit side) Front side bonded

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2899 Ft/Sec

MATERIAL:

Backing Board Exit: Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite Entrance: Air Logistics 114509-304

Self Sealing Exit: Goodyear Tire DX 325 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight

The backing board frayed and cored the size of the projectile. The self-sealing material sealed dry with no trace of fuel leakage. The skin was cored and petaled.

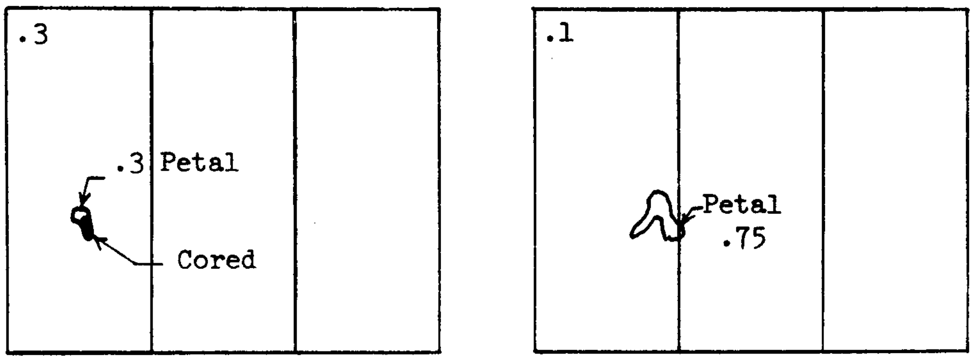
Exit: Tumbled exit.

The self-sealing material was pulled into box some but the wound had a damp seal between 2 and 3 minutes. The backing board was badly frayed. The skin was cored and petaled. The projectile struck the edge of a wood spacer on the skin.

BLOCK NUMBER B 48.1

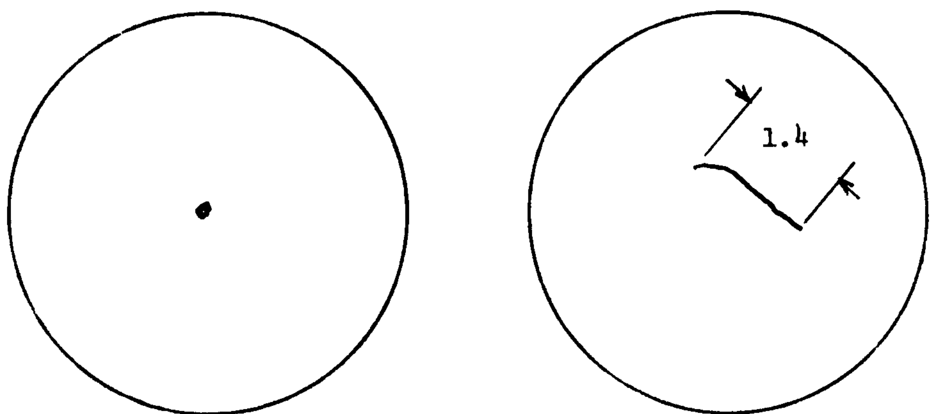
ROUND NUMBER T 35

ENTRANCE *EXIT



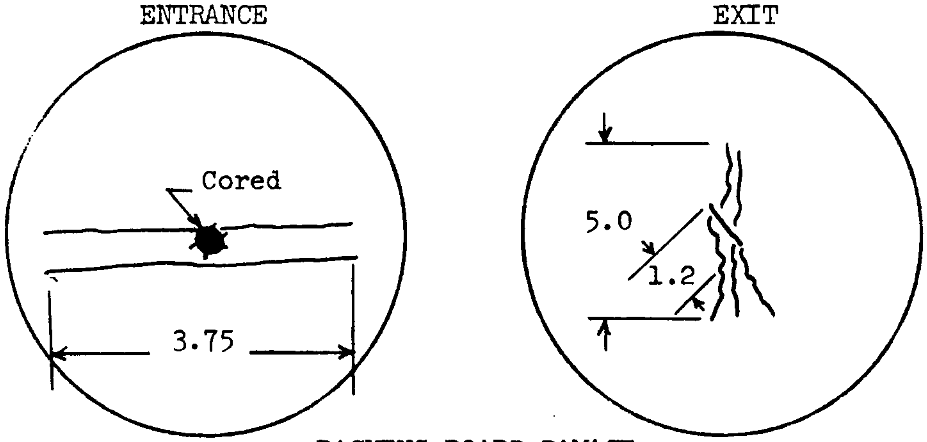
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 48.1 ROUND NUMBER T 36

DATE FIRED 13 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material Exit: 2024-T3 Clad (.080) Skin Gap 0 in. front
1.25 in. back

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity ------------- Ft/Sec

MATERIAL:

Backing Board Exit: Air Logistics 700 SI EN 2-41

Composite Entrance: Air Logistics 114509-304

Self Sealing Exit: Goodyear Tire DX 325 (Cal. 50)

RESULTS:

Entrance Seal no

Exit Seal yes

Entrance Cored yes

Exit Cored yes (BB)

COMMENTS:

Entrance: Tumble 6 inches below fuel surface in plain area of panel.

The backing board was frayed and cored badly. The self-sealing material was also cored and pulled loose from the skin. The skin was petaled .7 inches, cored and split. Ribs on the skin sheared the rivets and warped. The skin had very little strength left. Leakage was constant (full flow) with no slowing; thus failure.

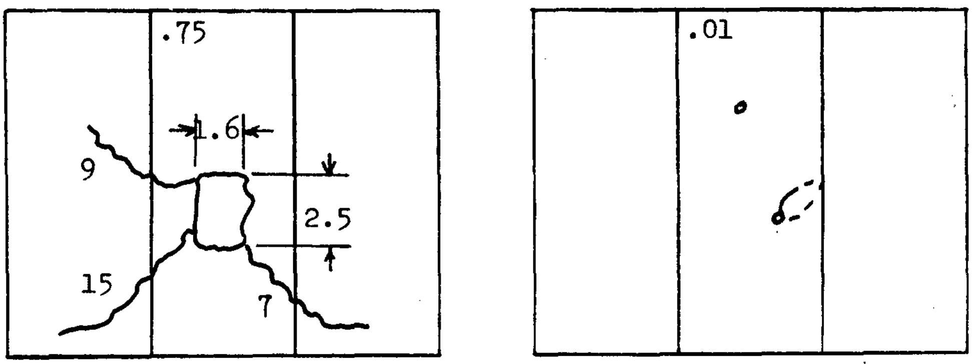
Exit: Tumble

The projectile struck a wood support and only the nose pierced the skin. The backing board was frayed and cored slightly. The self-sealing material sealed with no visible leakage. Therefore, entrance material failed; exit material passed.

BLOCK NUMBER B 48.1

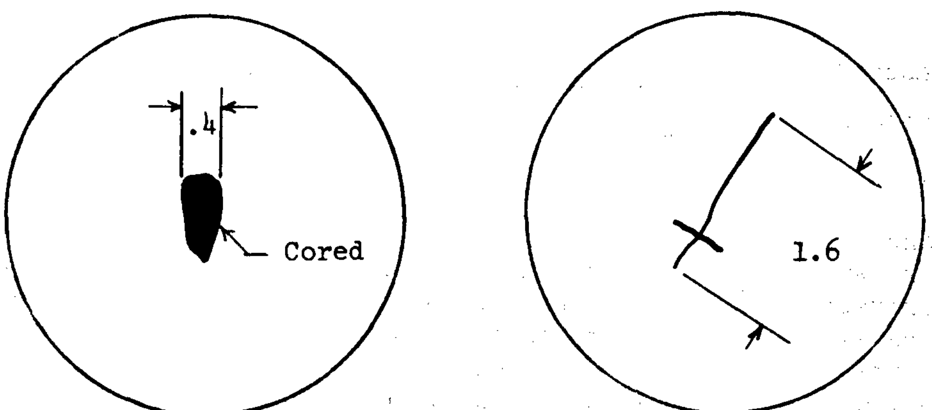
ROUND NUMBER T 36

ENTRANCE *EXIT



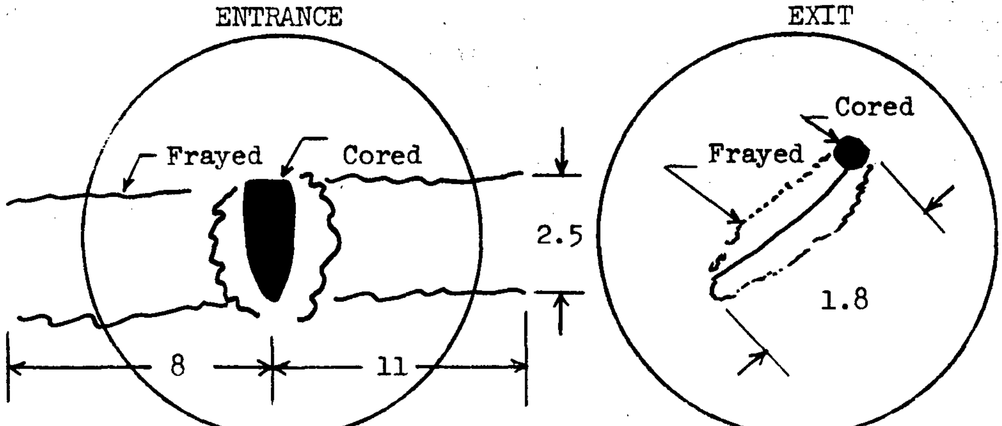
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 29 ROUND NUMBER T 37

DATE FIRED 14 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.080) Skin Gap 1.4 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2837 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ----------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight

A flash was seen at the entrance approximately 8 inches diameter and for approximately 1/2 second. A burn was also noted on the skin and backing board. The skin was cored and had a .3 inch petal. The backing board was frayed to the size of the projectile. The self-sealing material was cracked on the inside but did not leak even a trace of fuel.

Exit: Full tumble.

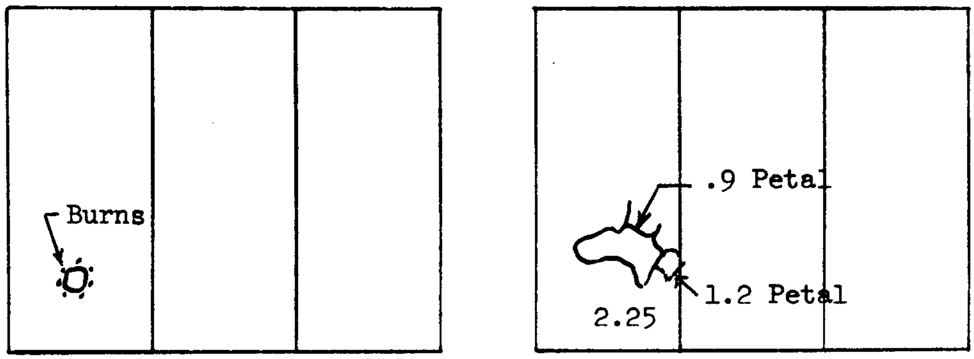
The skin was cored and petaled to a 1.2 inch maximum height. The backing board was torn and frayed over an area 6 inches x 9 inches but not cored. The self-sealing material was frayed on the exit side considerably. When the material was straightened back out the self-sealant did bond together. It was determined that it would not hold, though, with the backing board support destroyed. Leakage rate was unable to determine.

Failure on exit due to no support and material pulling into fuel tank.

BLOCK NUMBER B 29

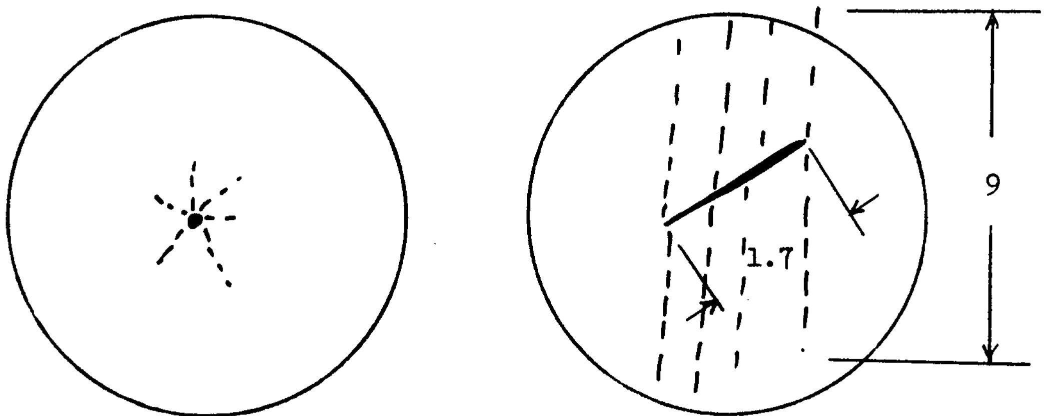
ROUND NUMBER T 37

ENTRANCE *EXIT



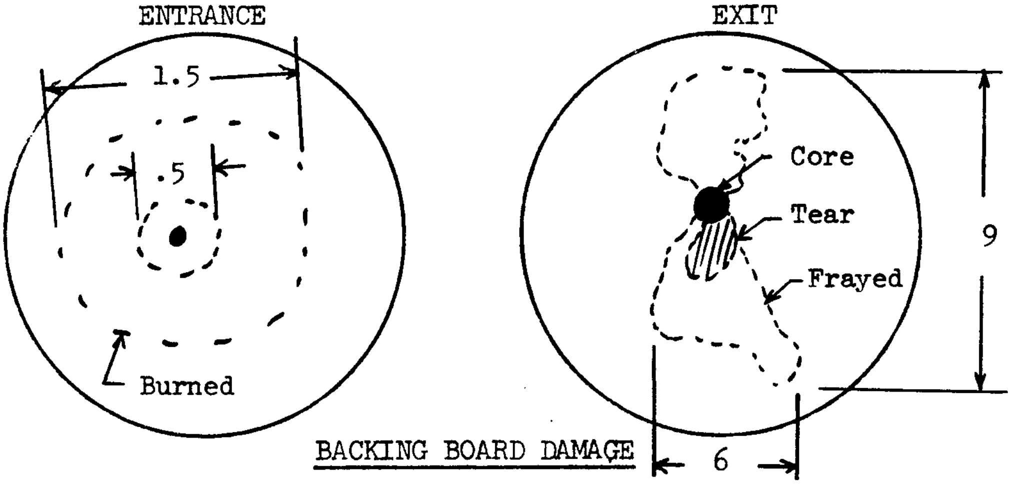
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 27 ROUND NUMBER T 38

DATE FIRED 18 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM-1800 (Cal. 50)

Composite ------------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: 12 inches below fuel surface.

The skin was petaled outward on 1/2 of hole and inward one 1/2 of hole. Petal height was .15 inches. The skin also cored. A flash was noted on entrance.

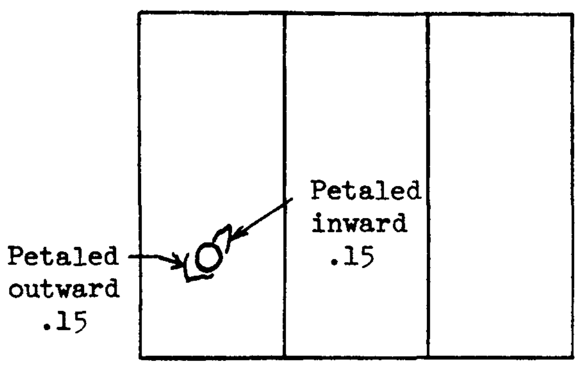
Exit: Full tumble 12 inches below fuel surface.

Failed skin completely. Petal was 6.5 inches high. The backing board held and the wound in self-sealing material was only damp. Several clamps were knocked off; broke 2 and warped end frame some. The exit flange assembly had to be removed and resealed.

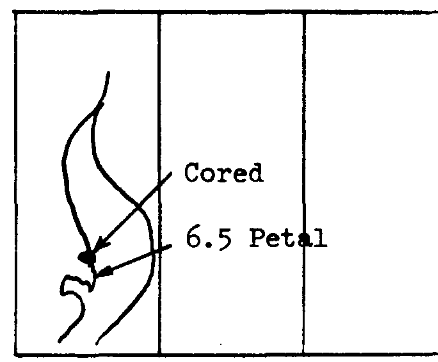
BLOCK NUMBER B 27

ROUND NUMBER T 38

ENTRANCE

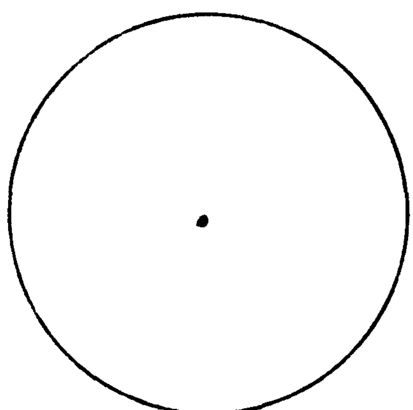


*EXIT

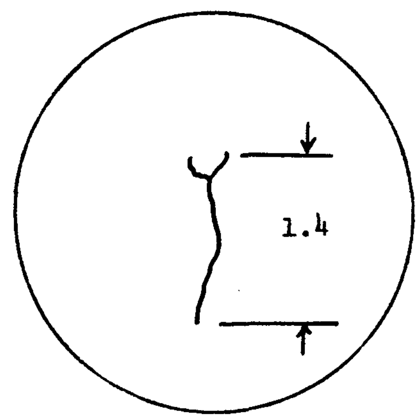


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

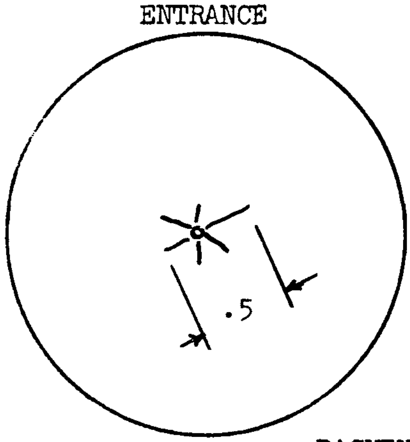


EXIT

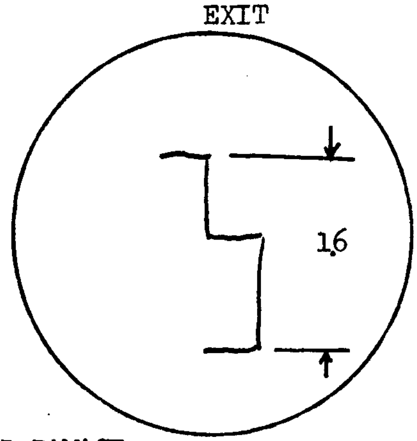


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 27 ROUND NUMBER T 39

DATE FIRED 18 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2920 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 1800 (Cal. 50)

Composite -------------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

A large flash was noted on entrance. The skin was cored and petaled slightly (.2 inches). The backing board had almost no damage and the self-sealing material was dry. There was no trace of fuel.

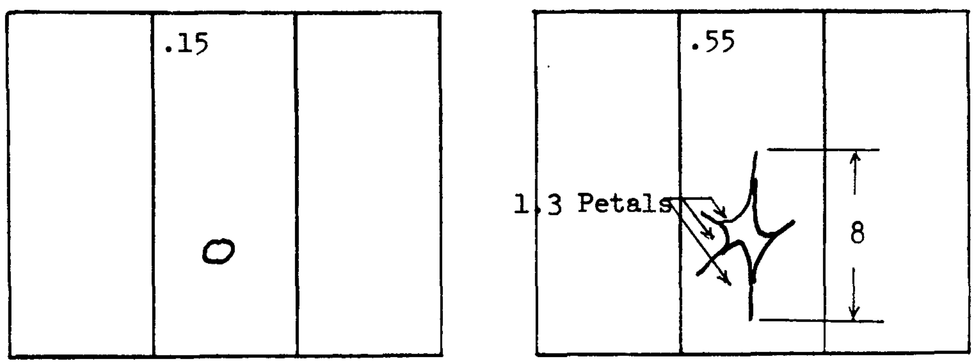
Exit: Straight 12 inches below fuel surface.

The first round that exited straight. The skin was slightly cored but petaled to 1.3 inches. The backing board held and self-sealing wound just bubbled. No drops fell from the specimen. The clamps all held because of straight entry and exit.

BLOCK NUMBER B 27

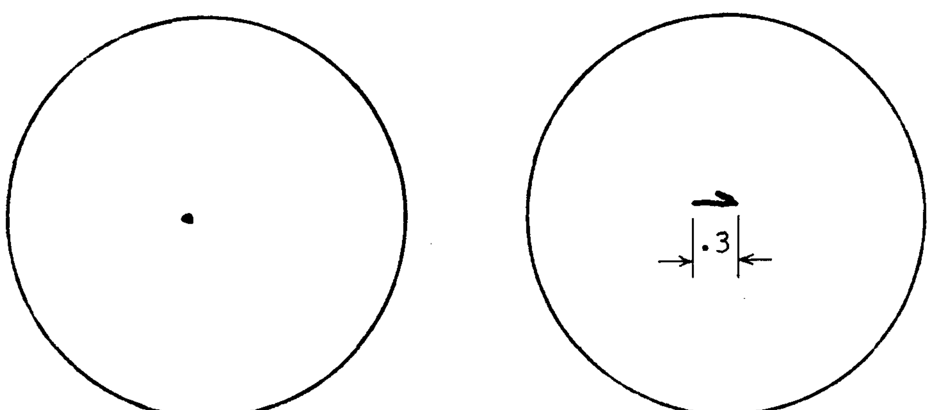
ROUND NUMBER T 39

ENTRANCE *EXIT



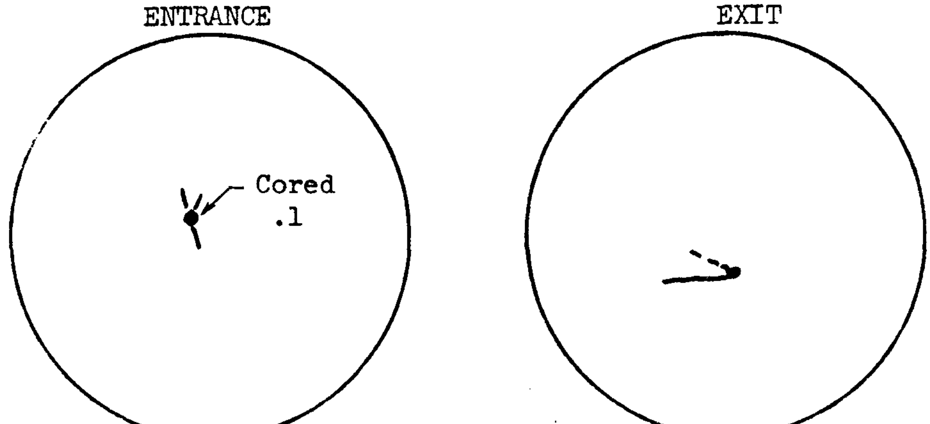
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 27 ROUND NUMBER T 40

DATE FIRED 18 December 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2963 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 1800 (Cal. 50)

Composite ----------------

Self Sealing Goodyear Tire FTL-11 3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel.

The skin was cored and petaled to .25 inches. The backing board held and the self-sealing material wound was dry.

Exit: Tumble 15 inches below fuel surface.

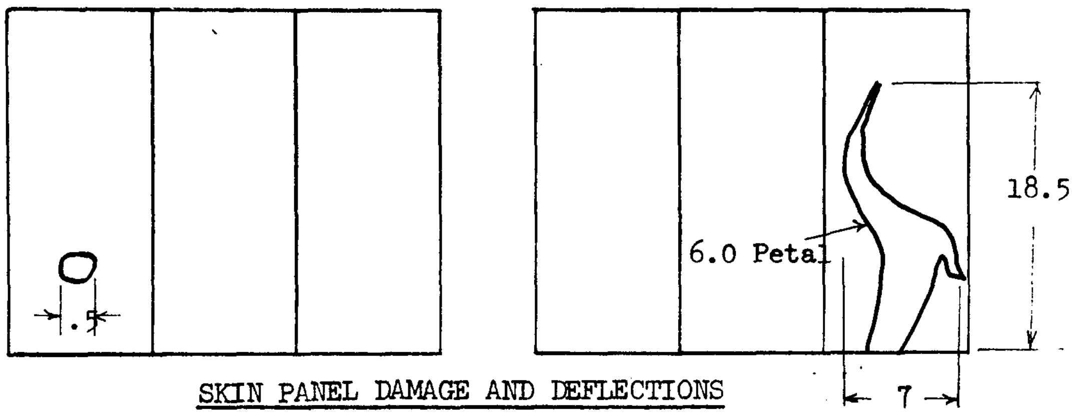
The skin was cored and split out for a total failure. The backing board did hold and the self-sealing material wound was only damp.

Clamps were broken (9) thus a leakage rate or amount was impossible to get. The self-sealing material was not pulled into the box, though. The back flange had to be resealed.

BLOCK NUMBER B 27

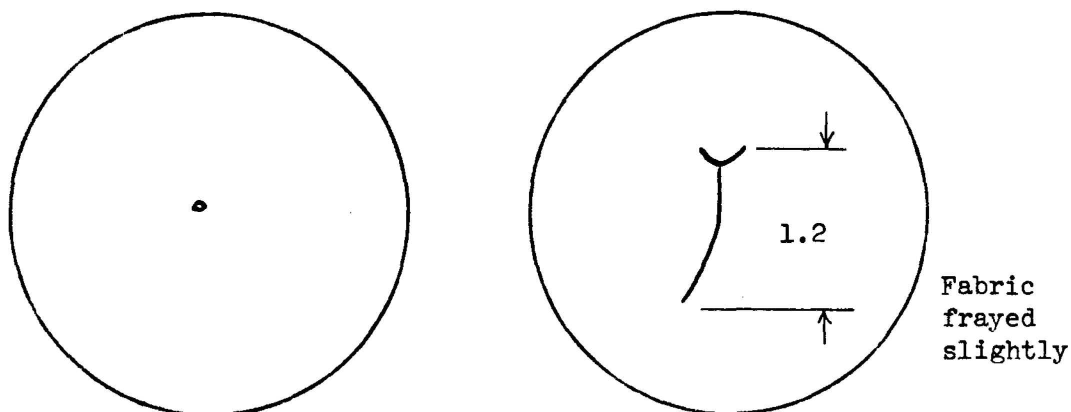
ROUND NUMBER T 40

ENTRANCE *EXIT



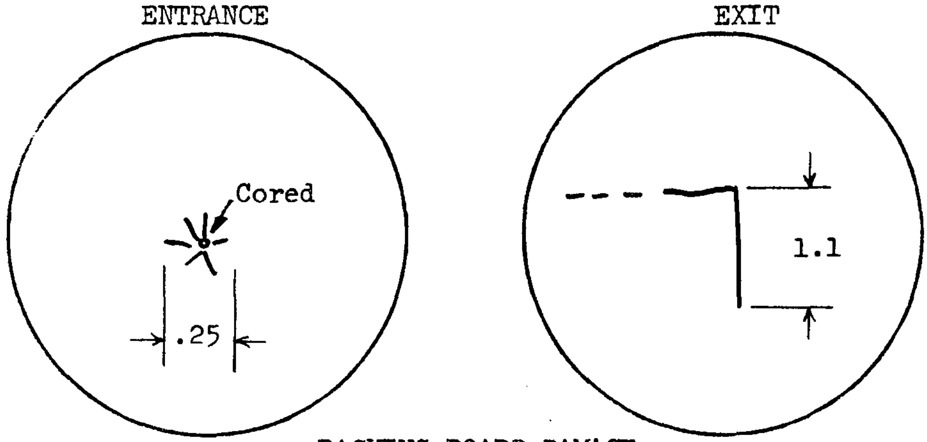
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 27 ROUND NUMBER T 41

DATE FIRED 18 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity 2797 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 1800 (Cal. 50)

Composite --------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Fully tumbled.

The skin was cored and split from top to bottom with a 9.5 inch high petal outward. The backing board held, though, with only a slit and bulge. The self-sealing material sealed dry in less than 2 minutes. A flash on entrance occurred.

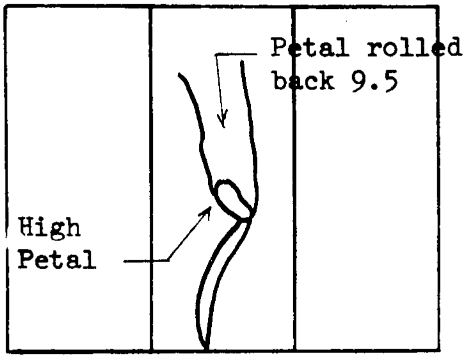
Exit: Partial tumble backward.

The skin split into a previous projectile wound (T-39) and was cored. The backing board held and the self-sealing material sealed dry in less than 1 minute. The leakage from the wounds was very slight; mostly just dripping. Several clamps were knocked off and fuel sprayed to the top of the gun butt from the top of the exit flange assembly. Projectile exited at zero velocity.

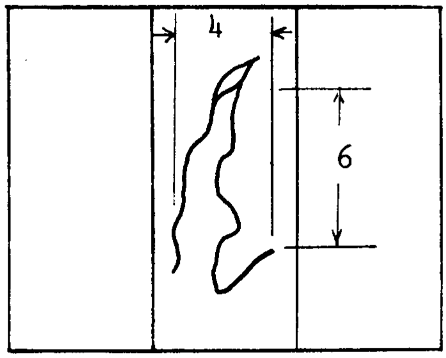
BLOCK NUMBER B 27

ROUND NUMBER T 41

ENTRANCE

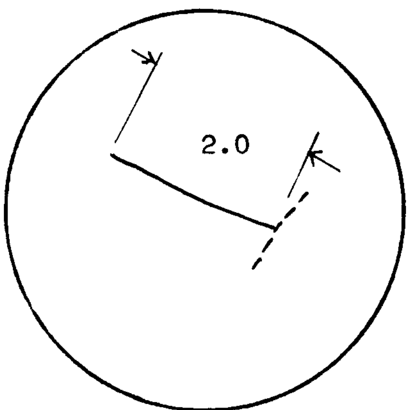


*EXIT

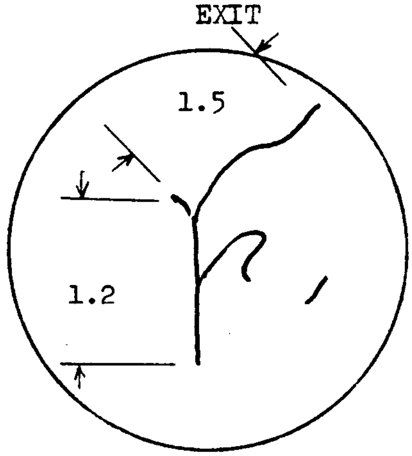


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

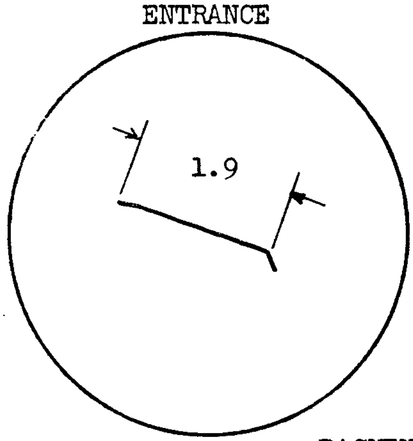


EXIT

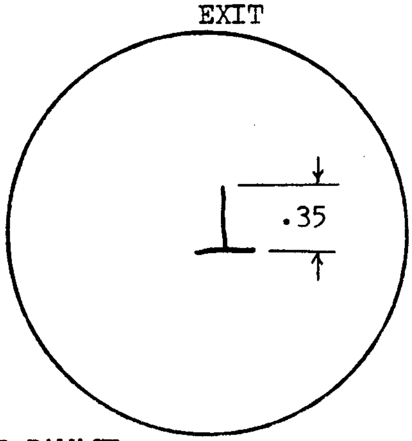


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 27 ROUND NUMBER T 42

DATE FIRED 18 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity 2703 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM-1800 (Cal. 50)

Composite --------------

Self Sealing Goodyear Tire FTL 11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Full tumble 6 inches below fuel surface.

The skin was cored the size of the projectile and split out from 4 inches of the top to bottom through previous T-38 wound. Petal was 2.4 inches outward. The backing board held thus giving support for self-sealing material. The material sealed damp in 2 minutes. An entrance flash was seen.

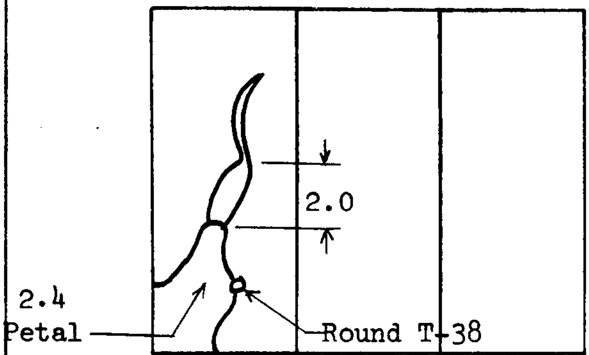
Exit: Part tumble 6 inches below fuel surface.

The skin was split more in T 38 wound and cut by projectile as shown. The backing board held and the self-sealing material had a dry seal in 3 minutes. Leakage was very small and unmeasurable due to leakage around flanges. All wounds bubbled some when pressure was applied for this shot. Exit of T 38 opened up and flowed some fuel. Impact of projectile knocked off the valve Christmas tree and fuel sprayed approximately 12 feet high from the cap. Three threads of a 3/8 tee (alum) were stripped.

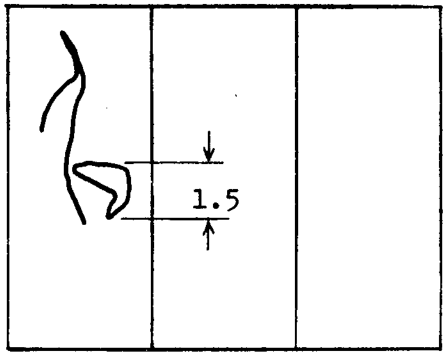
BLOCK NUMBER B 27

ROUND NUMBER T 42

ENTRANCE

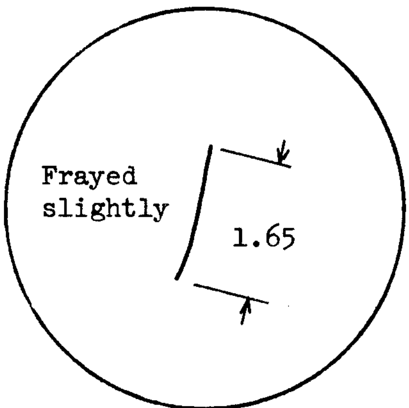


*EXIT

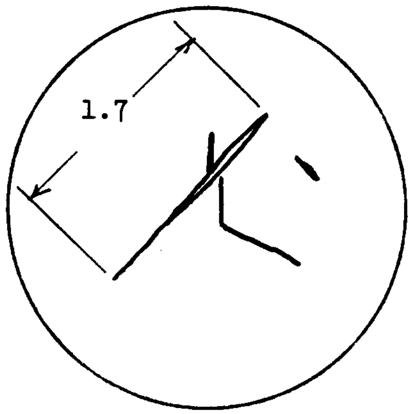


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

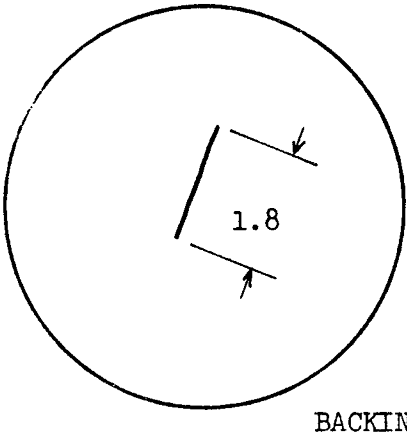


EXIT

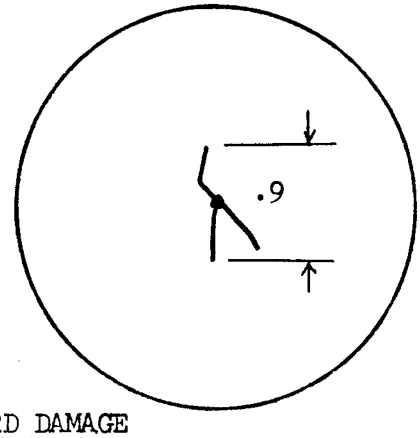


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 13 ROUND NUMBER T 43

DATE FIRED 19 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material None Skin Gap NA

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity ------------- Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal yes Exit Seal no - reduced rate

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

The backing board was bonded on both sides of the self-sealing material. The backing was frayed. The self-sealing was dry after impact thus no fuel escaped.

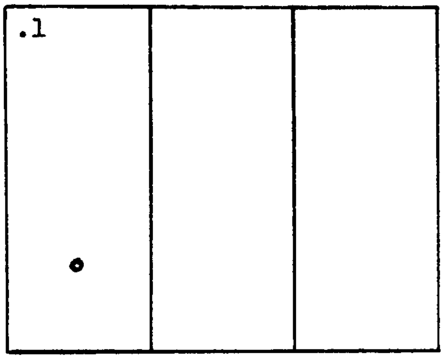
Exit: Full tumble 15 inches below fuel surface.

The backing board was once again frayed considerably larger than the self-sealing wound. The self-sealing material leaked a stream of fuel for 30 seconds, then leaked at a fast dripping rate slowing to 150 drops/minute constant after 3 minutes.

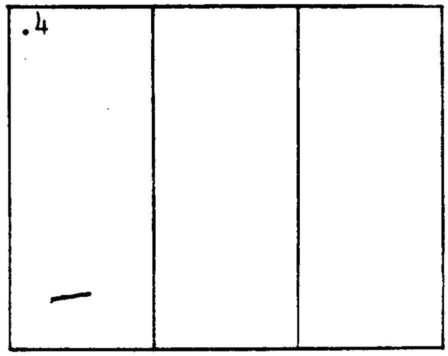
BLOCK NUMBER B 13

ROUND NUMBER T 43

ENTRANCE

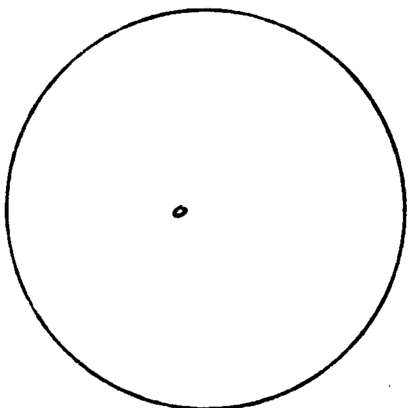


*EXIT

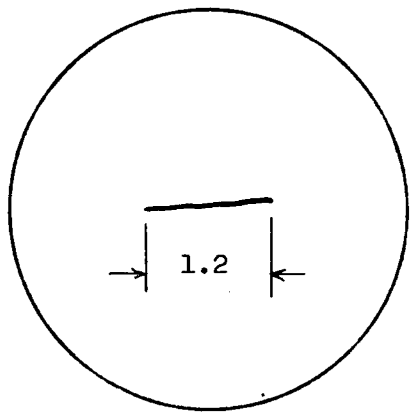


COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

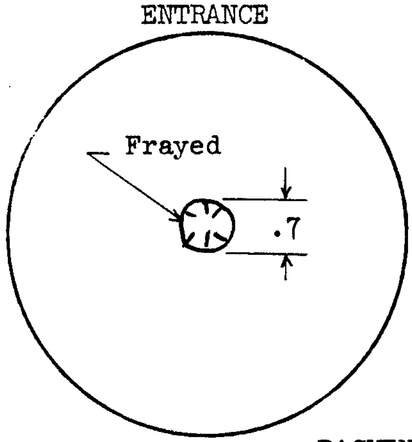


EXIT

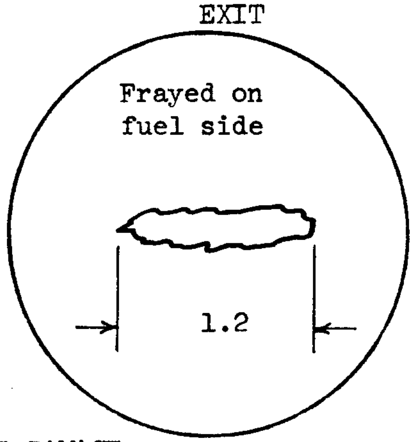


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 13 ROUND NUMBER T 44

DATE FIRED 19 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material None Skin Gap NA

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2614 Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

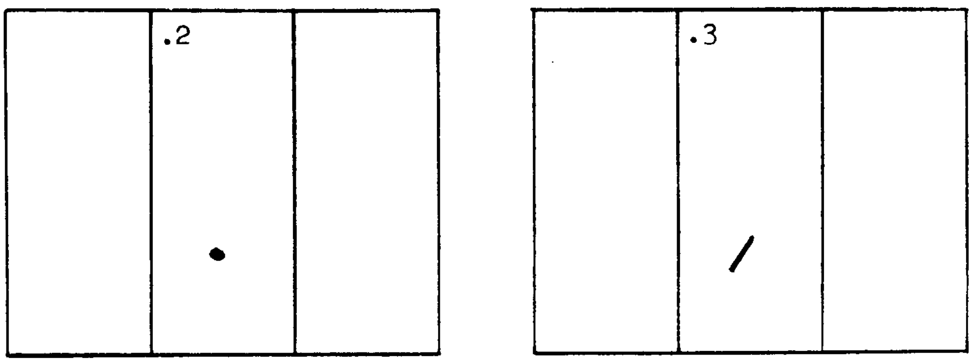
When pressurized round T 43 exit wound opened and flowed fuel at rate of 100 ml./min.

Entrance: Straight 12 inches below fuel surface.
The backing board was frayed but the self-sealing material sealed dry immediately.

Exit: Tumbled 14.5 inches below fuel surface.
The backing board was frayed badly. The self-sealing material leaked a small stream slowing very little in two minutes. When pressure was reduced to zero the leakage slowed to 1 drop/5 seconds constant for the rest of the test.

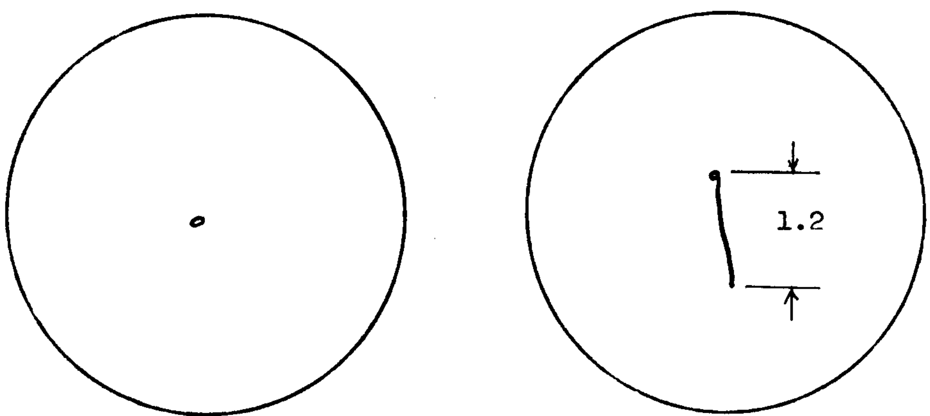
BLOCK NUMBER B 13
ROUND NUMBER T 44

ENTRANCE | *EXIT



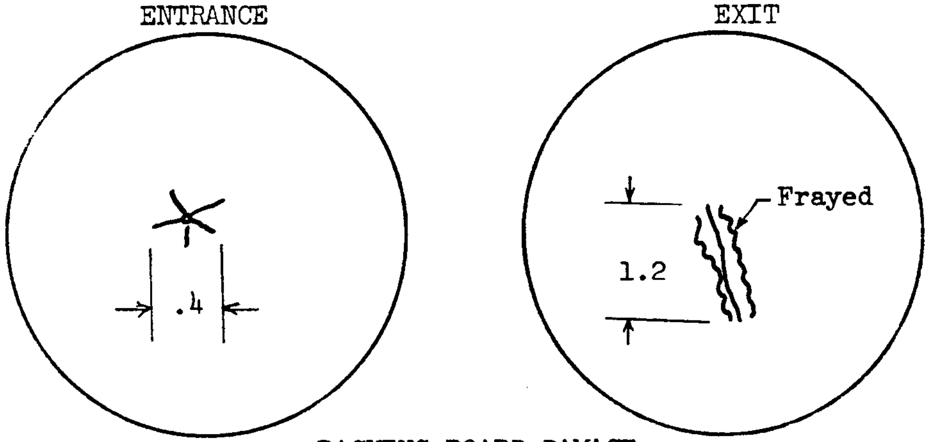
COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 13 ROUND NUMBER T 45

DATE FIRED 19 December 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material None Skin Gap NA

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2649 Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

When pressurized exit wounds of T 43 and T 44 opened leaking fuel.

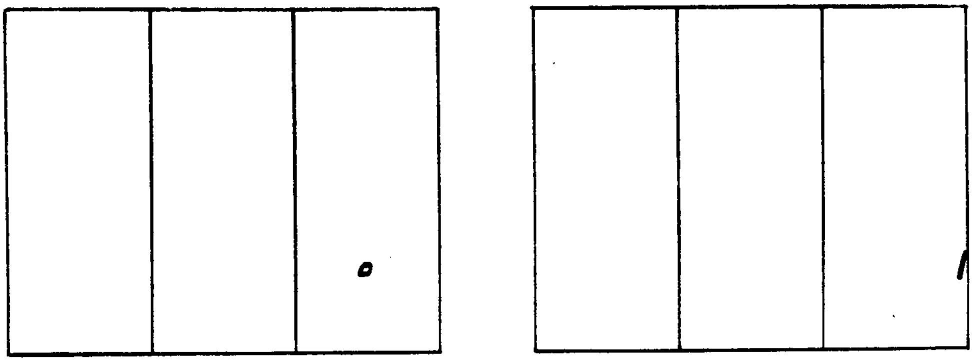
Entrance: Straight 12 inches below fuel surface.
The backing board was frayed but the self-sealing material was dry upon inspection.

Exit: Tumble 13 inches below the fuel surface.
The round hit a wood support thus no exit was obtained. The backing board was frayed less due to the extra support from the wood. The self-sealing material was slit and leaked a drippage rate. When pressure reduced to zero the wound continued to seep for the rest of the test.

BLOCK NUMBER B 13

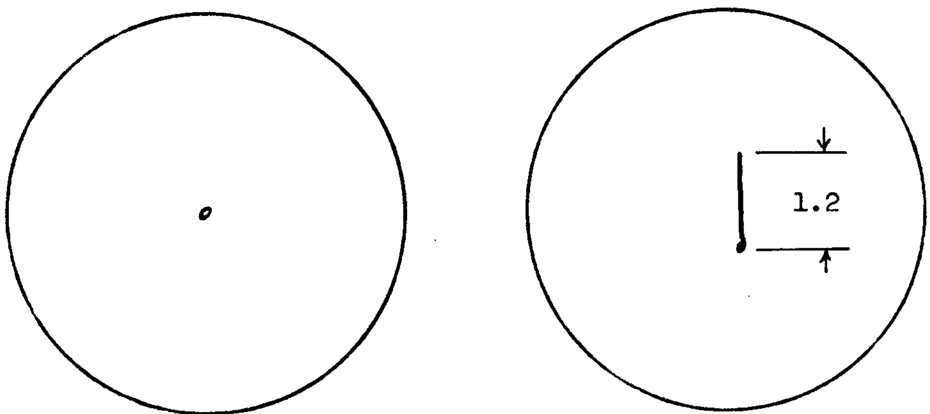
ROUND NUMBER T 45

ENTRANCE *EXIT



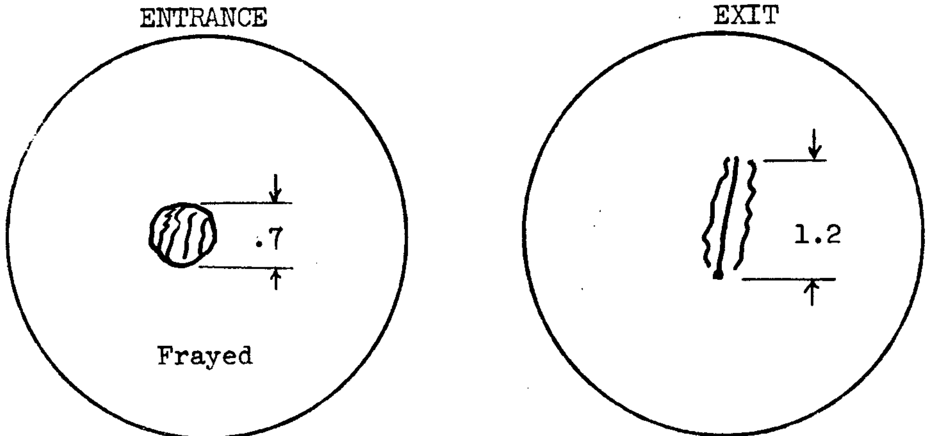
COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 13 ROUND NUMBER T 46

DATE FIRED 19 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material None Skin Gap NA

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity 2532 Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: Partially tumbled 3 inches below fuel level.

Round actually overtumbled and entered the cell backwards. The backing board was frayed and cored. The self-sealing material sealed damp immediately and dry seal in 3 minutes.

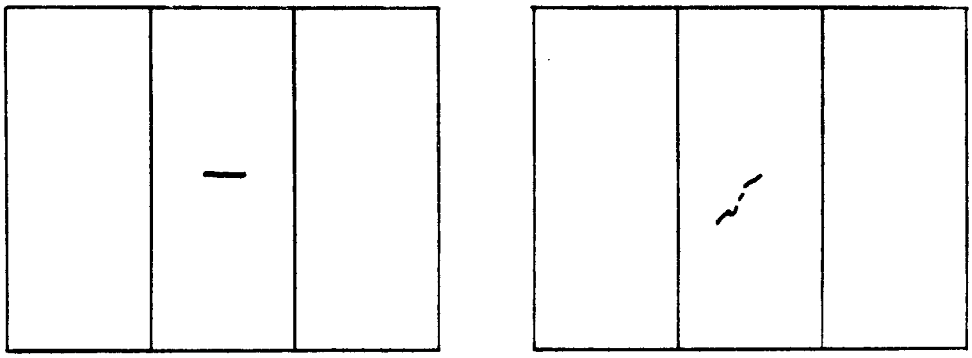
Exit: None. Tumbled attempt 3 inches below fuel level.

The backing board was penetrated but the self-sealing material was only cracked.

BLOCK NUMBER B 13

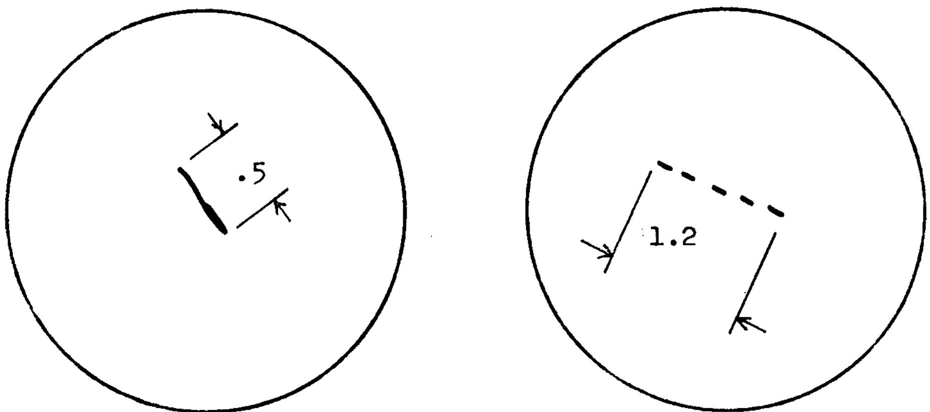
ROUND NUMBER T 46

ENTRANCE *EXIT



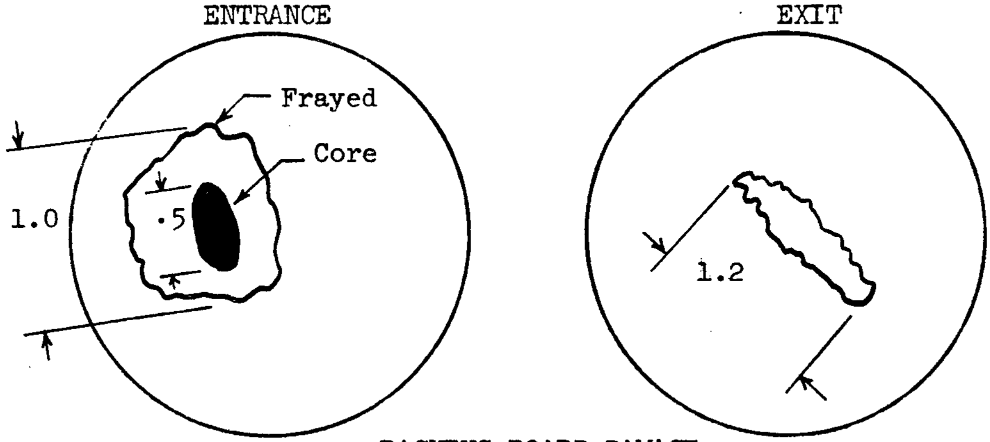
COMPOSITE PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 13 ROUND NUMBER T 47

DATE FIRED 19 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material None Skin Gap NA

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity ------------ Ft/Sec

MATERIAL:

Backing Board None

Composite Air Logistics 114509-217

Self Sealing None

RESULTS:

Entrance Seal no Exit Seal no

Entrance Cored yes Exit Cored yes

COMMENTS:

Tank lost pressure immediately upon impact.

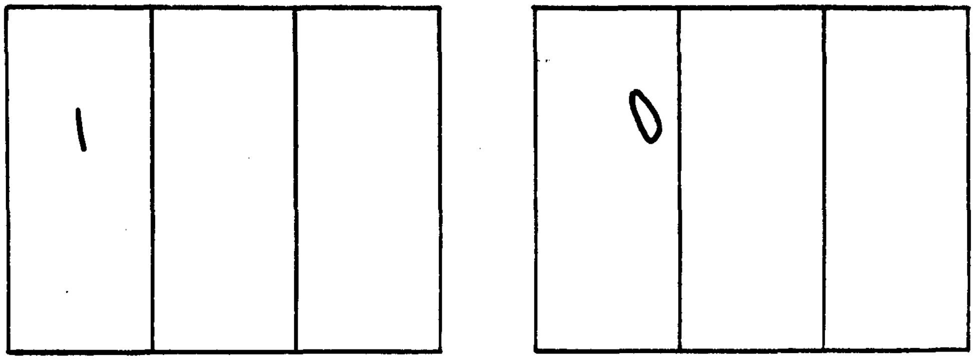
Entrance: 3/4 full tumbled at fuel level.
The backing board was cored and frayed. The self-sealing material was cored slightly.

Exit: Tumbled 1 inch above fuel level.
The backing board was frayed and cored badly. The self-sealing material was cored badly and misaligned some. Fueled tank to a higher fuel height at zero pressure. Both exit and entrance wounds leaked with no reduction of rate in 2 minutes. Leakage rate was 4 gallon/minute. Upon disassembly of the tank, self-sealing material corings were found inside.

BLOCK NUMBER B 13

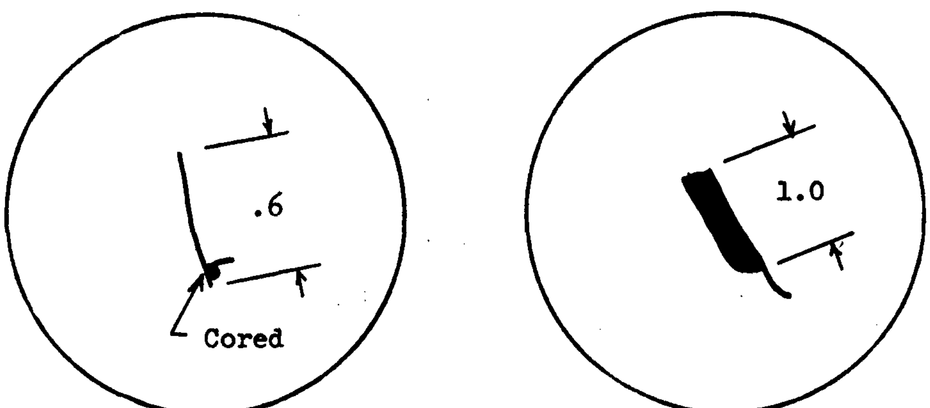
ROUND NUMBER T 47

ENTRANCE | *EXIT



COMPOSITE PANEL DAMAGE AND DEFLECTIONS

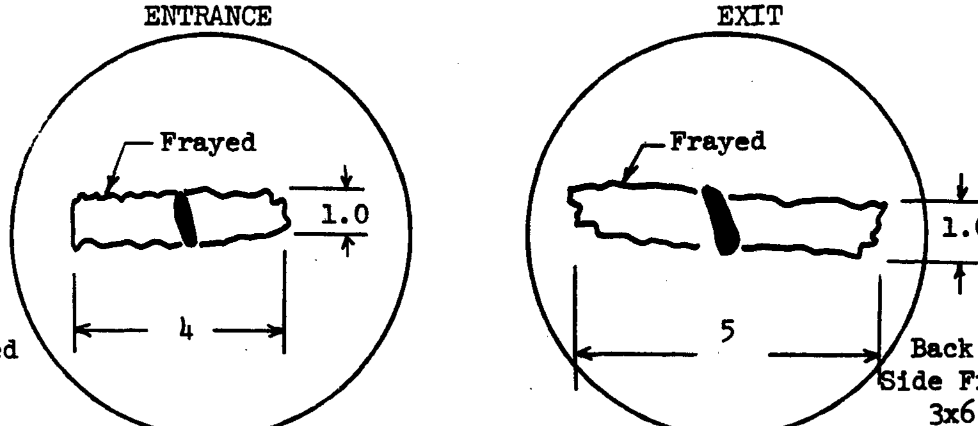
ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT

Back
Side Frayed
1.5 x 11



Back
Side Frayed
3x6

BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 26 ROUND NUMBER T 48

DATE FIRED 21 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 1.5 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2837 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite --------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes   Exit Seal no

Entrance Cored no   Exit Cored no

COMMENTS:

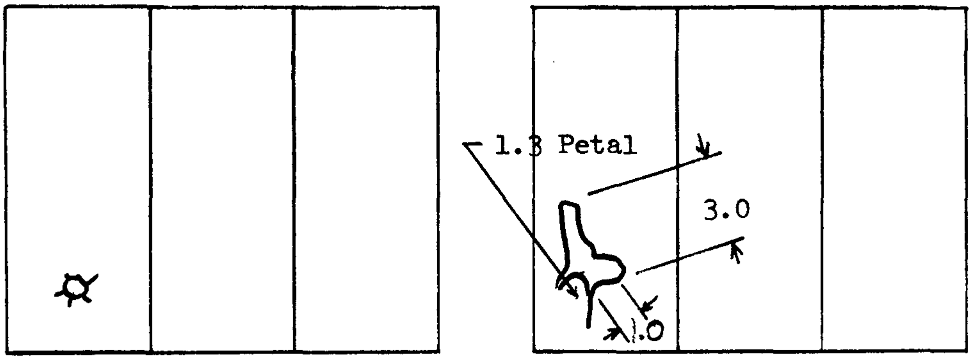
Entrance: Straight 11 inches below fuel surface.
A flash occurred on entrance. The skin was cored and petaled to .2 plus some burn marks. The backing board was only frayed in a .35 diameter area. The self-sealing material sealed with no trace of fuel leakage.

Exit: Partially tumbled 13 inches below fuel surface.
The skin was torn and petaled to 1.3 inches. Also coring took place. The backing board split out from 15 inches thus giving no support for the self-sealing material. The self-sealing material was pulled into the box on the lower corner, thus the wound was misaligned and could not seal. The new clamps held but clamps on either side of them failed. Four of the seven clamps knocked off were broken. The back panel was removed and resealed. The exit wound was supported with cardboard for the rest of the test.

BLOCK NUMBER B 26

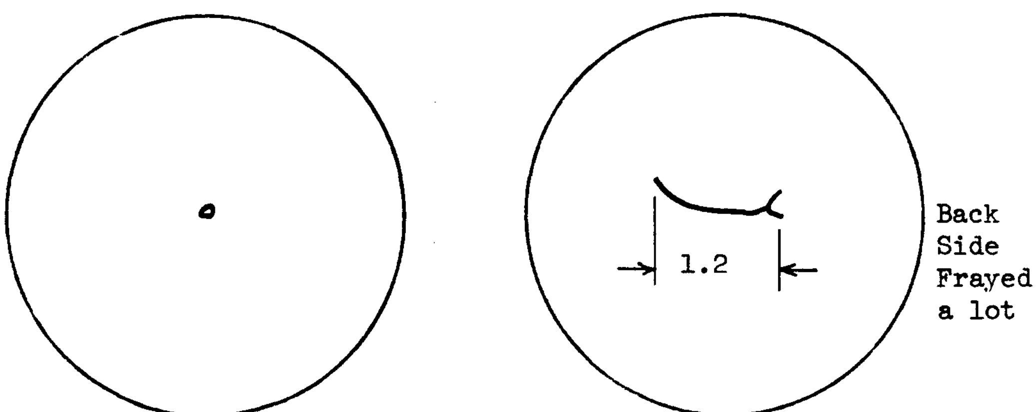
ROUND NUMBER T 48

ENTRANCE *EXIT



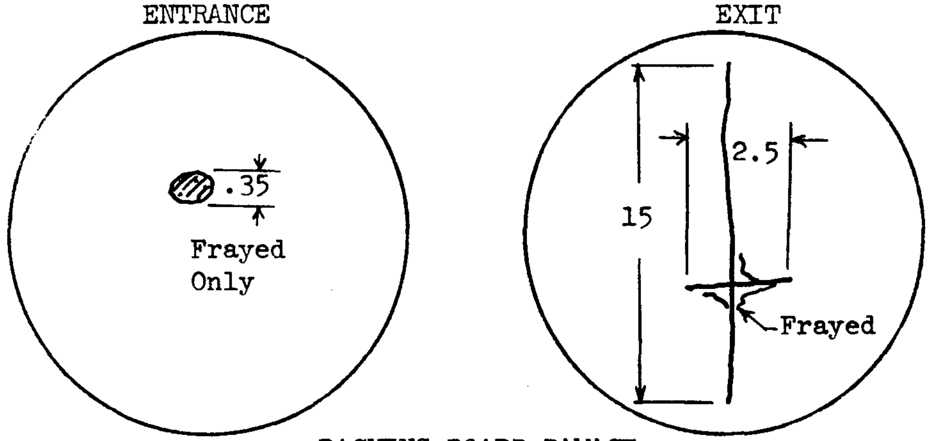
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 26 ROUND NUMBER T 49

DATE FIRED 21 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 1.5 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite --------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface. Very small flash on entrance.

The skin was cored and petaled. Backing board was frayed to a diameter less than the projectile diameter. The self-sealing material showed no trace of fuel leakage.

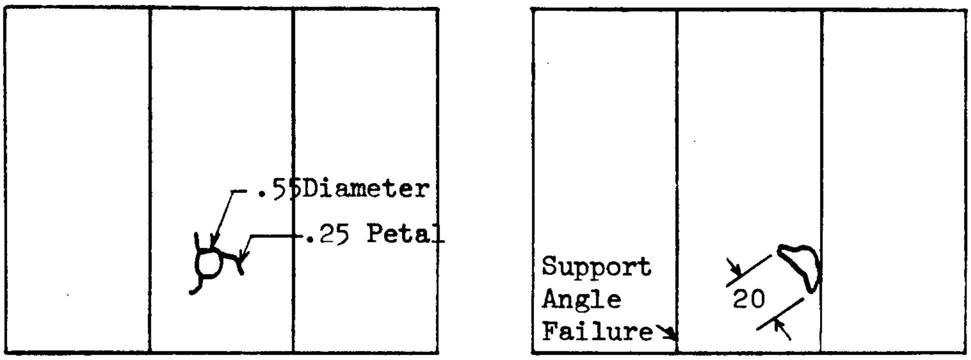
Exit: Tumbled 11 inches below the fuel surface.

The skin was cored and petaled. The backing board was frayed. The self-sealing material was sealed damp in 30 seconds and sealed dry shortly after. The support angle on the exit panel failed and moved out approximately 1.50 inches. However, the support angle failure did not seem to affect the sealing time, so the test was continued with no changes. Clamps held but allowed the flanges to leak.

BLOCK NUMBER B 26

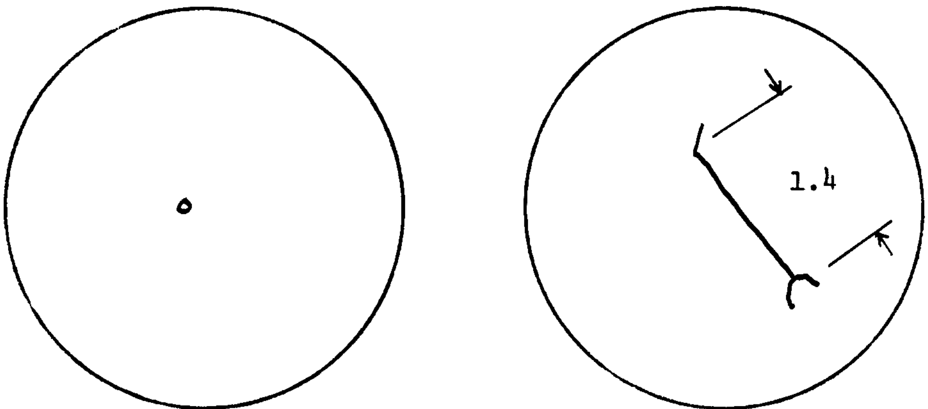
ROUND NUMBER T 49

ENTRANCE *EXIT



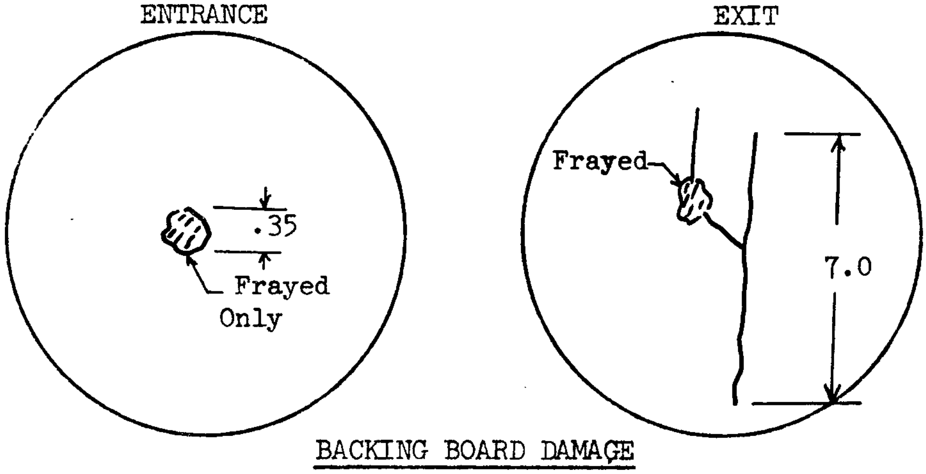
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 26 ROUND NUMBER T 50

DATE FIRED 21 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 1.5 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity ------------ Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite --------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored yes (SS)

COMMENTS:

Entrance: A large flash was observed on entry. Three-fourths tumbled 6 inches below fuel surface next to right side of box.

The skin was cored and petaled. The backing board was cored and frayed badly. Some skin corings had splattered the backing board and self-sealing material. The self-sealing material sealed damp immediately but pulled into the box.

Exit: Partially tumbled 10 inches below the fuel surface.

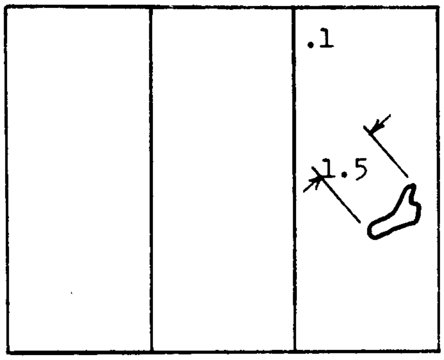
The skin was cored. The backing board split but did support the self-sealing material. The self-sealing material was cored slightly but obtained damp seal immediately and a dry seal in 3 minutes.

Had to remove front panel and reseal material around the flange.

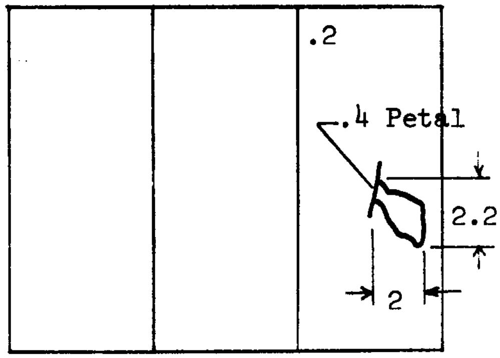
BLOCK NUMBER B 26

ROUND NUMBER T 50

ENTRANCE

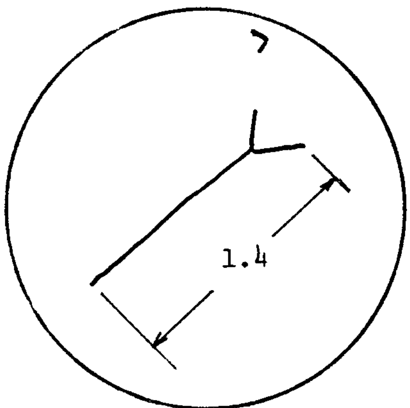


*EXIT

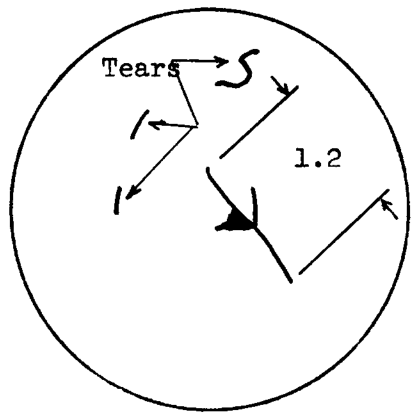


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

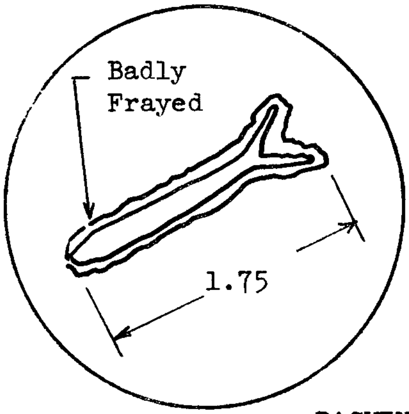


EXIT

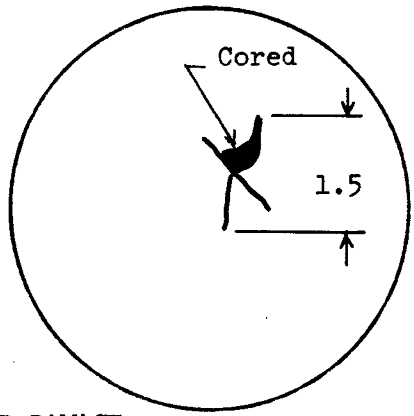


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 26 ROUND NUMBER T 51

DATE FIRED 22 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 1.5 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity 2740 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite ----------------

Self Sealing Goodyear Tire FTL-11-3 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored yes Exit Cored no

COMMENTS:

Entrance: Full tumble 6.5 inches below fuel surface.

A large flash was seen on entrance. Skin cored and petaled .3 inches. The backing board split and frayed badly. The self-sealing material flowed fuel for 1.5 minutes obtaining a damp seal at 2 - 2.5 minutes and a dry seal in 6 minutes. The material was cored slightly. Total leakage was .5 gallon from wound.

Exit: Tumble attempt 6 inches below fuel surface.

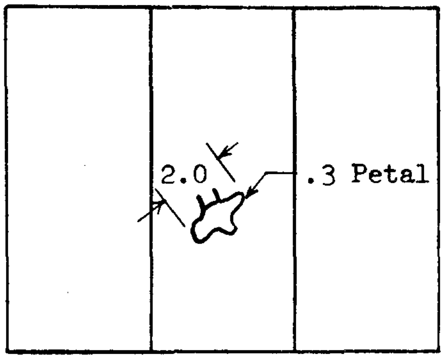
The skin was tested with the nose and tail of the projectile spliting the skin. The projectile then bounced back into the fuel box. The backing board was only slightly damaged with no loss of support. The self-sealing material obtained a damp seal immediately.

The specimen lost pressure upon impact due to clamps being knocked off. However, when sealed back up and refueled the box was pressurized to 2 psi. All wounds held with no dampness showing.

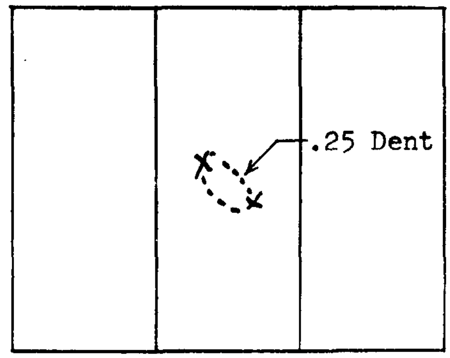
BLOCK NUMBER B 26

ROUND NUMBER T 51

ENTRANCE

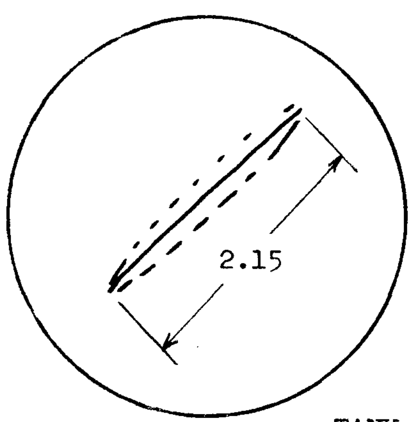


*EXIT

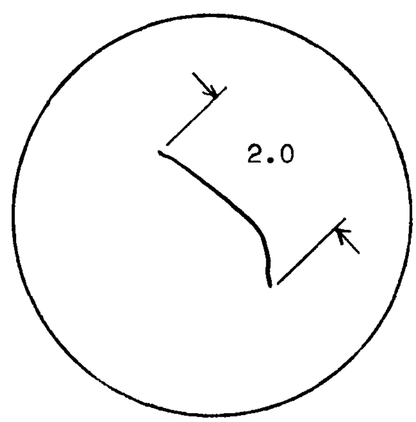


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

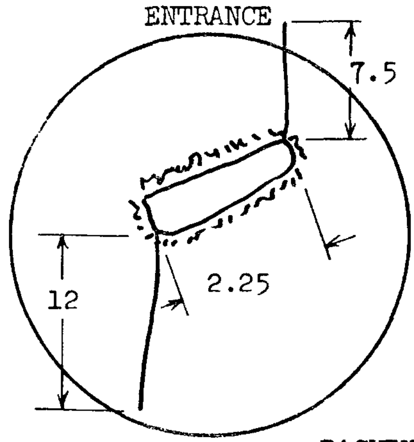


EXIT

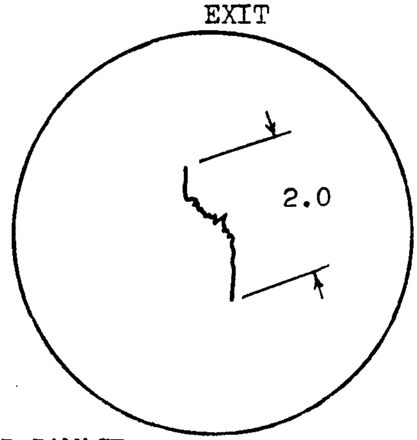


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 34 ROUND NUMBER T 52

DATE FIRED 22 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite --------------

Self Sealing Uniroyal US-173 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight

The skin was cored to diameter of projectile with some signs of burns. The backing board was only frayed the diameter of the projectile. The self-sealing material sealed dry with no trace of fuel.

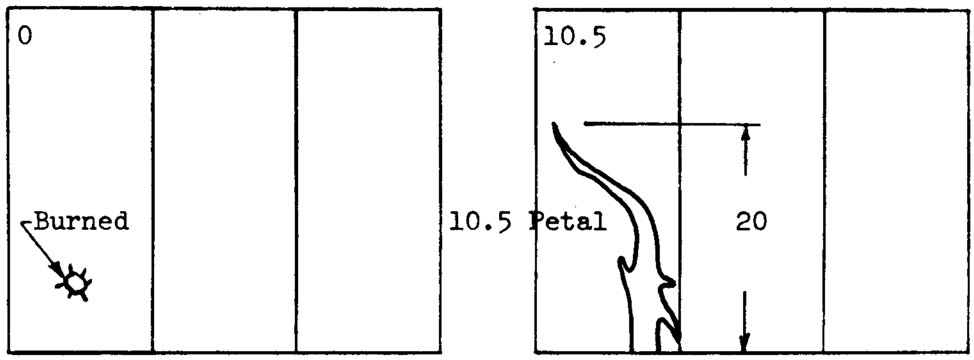
Exit: Partially tumbled.

The skin was cored slightly and torn badly with a 10.5 inch petal. The backing board was split for 5 inches and was the size of the skin. The self-sealing material was pulled into the box thus misaligning the wound for no chance of sealing. The load on one of the support angles caused a failure in the weld. The angle was bent out 10.5 inches. The projectile hit next to the adjacent support angle.

BLOCK NUMBER B 34

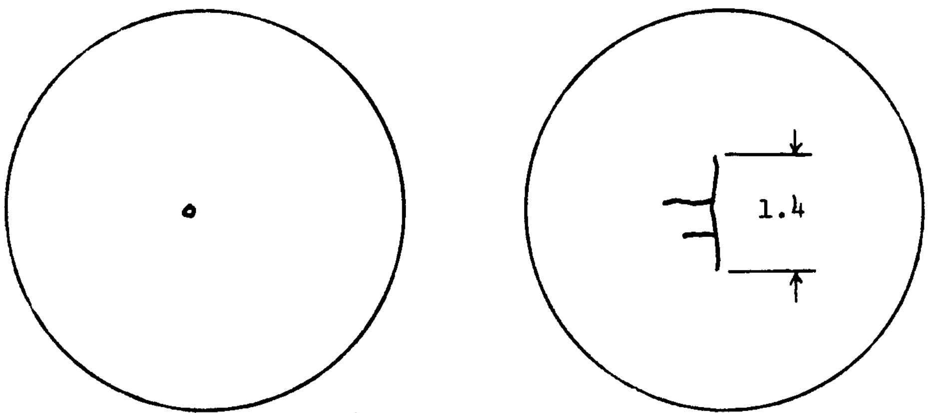
ROUND NUMBER T 52

ENTRANCE *EXIT



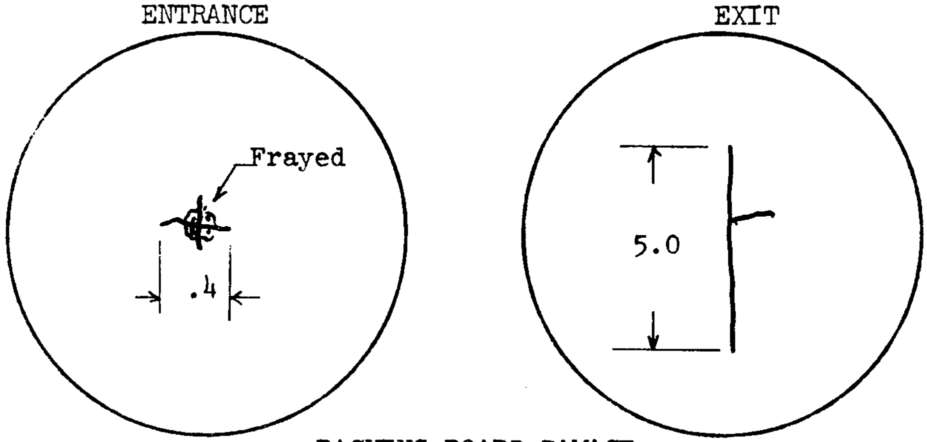
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 34 ROUND NUMBER T 53

DATE FIRED 29 December 1967

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite ------------------

Self Sealing Uniroyal US-173 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

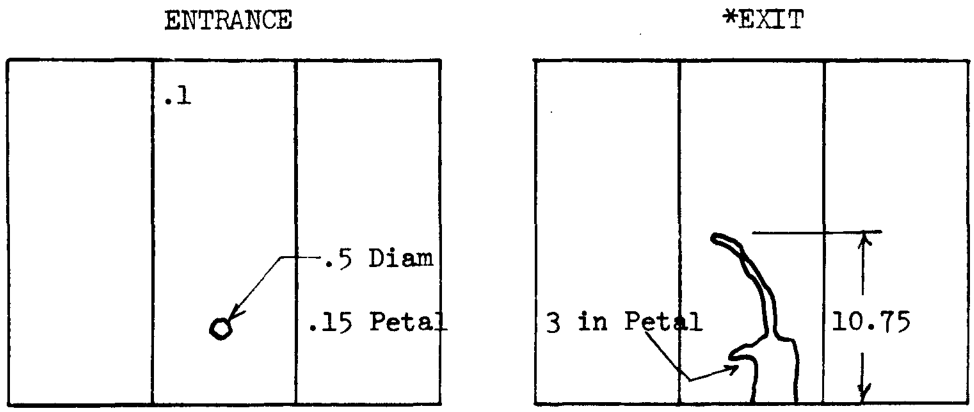
When pressurized to 2 psi, exit of round T 52 seeped continuously.

Entrance: Straight 12.5 inches below fuel surface.
When tank was impacted by the projectile the flanges let go, thus the pressure went from 2 psi positive to a vacuum. The skin was cored and petaled with metal corings stuck in the backing board. The self-sealing material leaked slightly but obtained a damp seal in less than 1 minute.

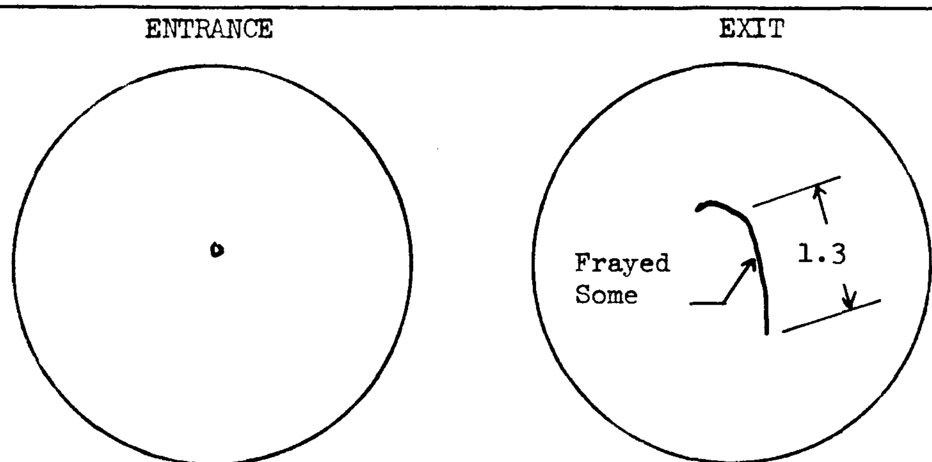
Exit: Tumbled 16 inches below fuel surface.
The skin was torn, cored and petaled, 3 inches maximum. The backing board was split but not cored. The self-sealing material was misaligned thus no chance for a seal. Had to reseal rear panel. Impact shock warped end frame assembly very badly.

BLOCK NUMBER B 34

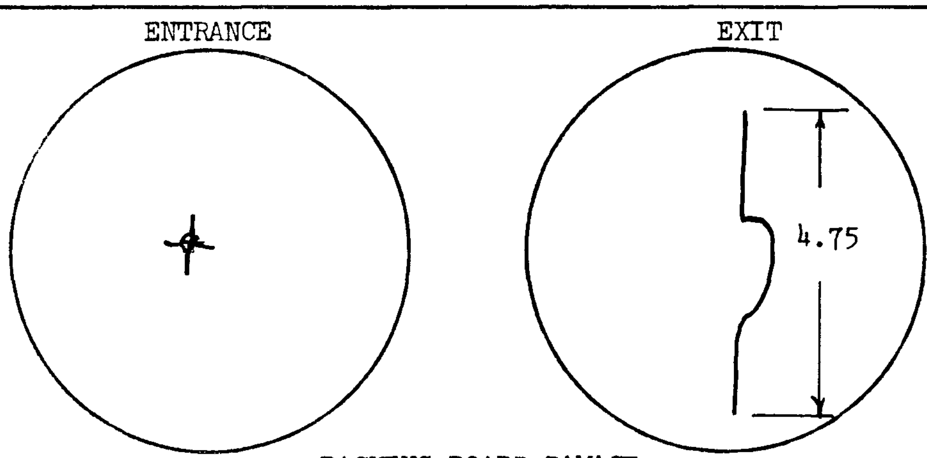
ROUND NUMBER T 53



SKIN PANEL DAMAGE AND DEFLECTIONS



TANK DAMAGE



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 34 ROUND NUMBER T 54

DATE FIRED 29 December 1967

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity ---------- (15% reduced round) Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite -----------------

Self Sealing Uniroyal US-173 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal only at 0 pressure

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 11 inches below fuel surface.

The skin was cored and petaled. The self-sealing material obtained a damp seal immediately at 1 psi. The backing board held fine with little damage.

Exit: Tumble 10 inches below fuel surface.

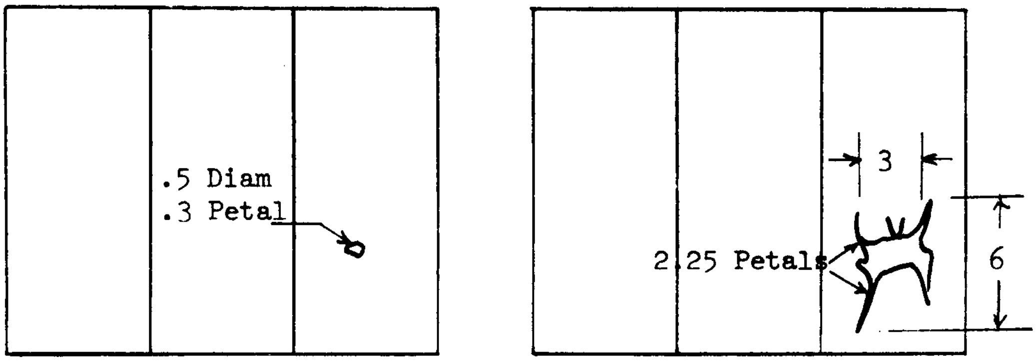
The skin was cored and petaled 2.25 inches maximum high. The projectile split the backing board and self-sealing material. The self-sealing material leak would slow only when the pressure was reduced. Rates were .25 gallon/ minute 1 psi and dripping at zero psi.

The projectile shock also opened exit wounds of T 52 and T 53 rounds. They continued to flow small streams.

BLOCK NUMBER B 34

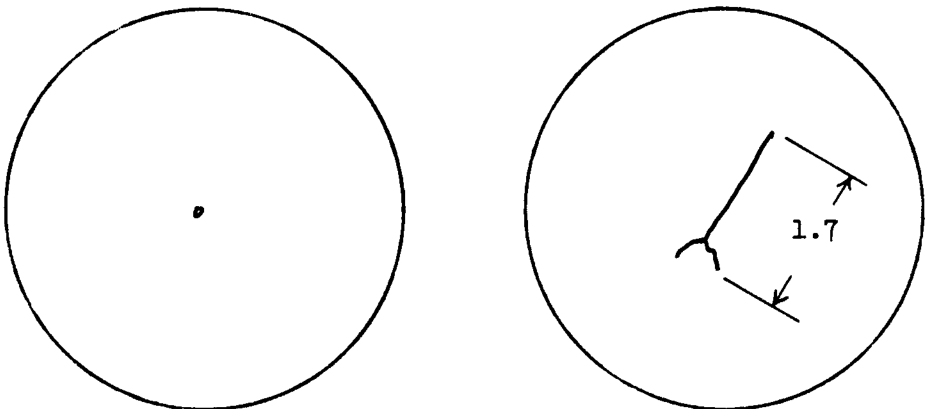
ROUND NUMBER T 54

ENTRANCE | *EXIT



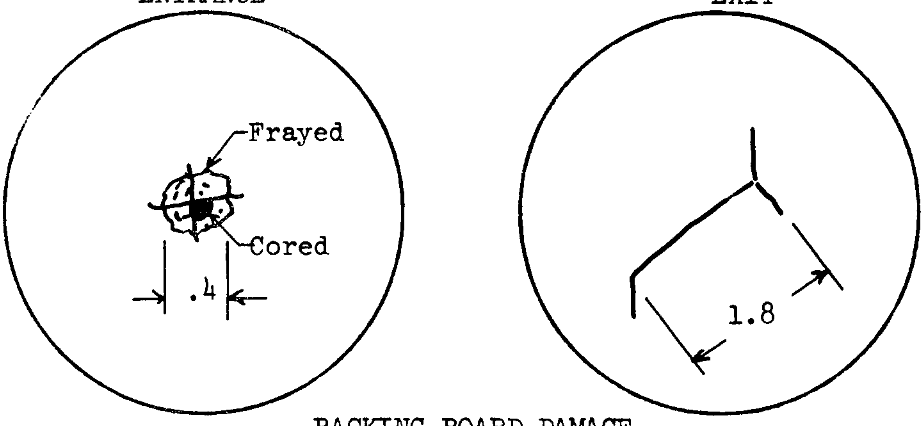
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 34 ROUND NUMBER T 55

DATE FIRED 20 December 1967

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity --------------- Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 018 (Cal. 50)

Composite ----------------

Self Sealing Uniroyal US-173 (Cal. 50)

RESULTS:

Entrance Seal no Exit Seal yes

Entrance Cored yes Exit Cored no

COMMENTS:

Large flash on impact. The projectile struck steel support angle on impact and broke as it entered the cell.

Entrance: Tumbled 4 inches below fuel surface.

The skin was cored and badly shattered. The backing board was frayed and cored. The self-sealing material was also cored slightly but cut badly. The leakage was 3/4 gallon/minute constant at zero pressure.

Exit: None

The skin was dented. The backing board just had one hole in it. The self-sealing material had two cuts but neither showed any sign of leakage. When the cell was torn down the following was found inside:

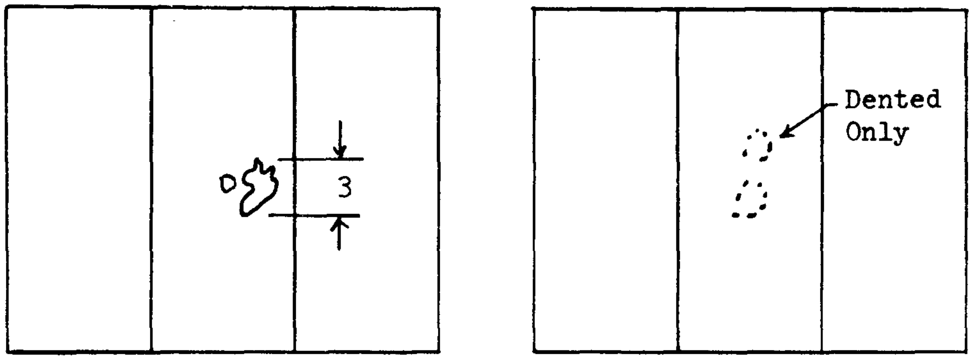
Projectile broken in two pieces, skin coring, self-sealing material and backing board corings.

The exit on T 53 opened up flowing full flow.

BLOCK NUMBER B 34

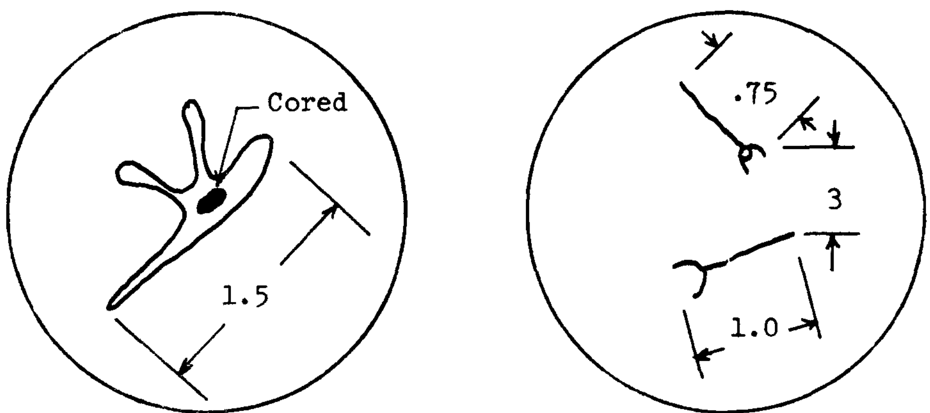
ROUND NUMBER T 55

ENTRANCE *EXIT



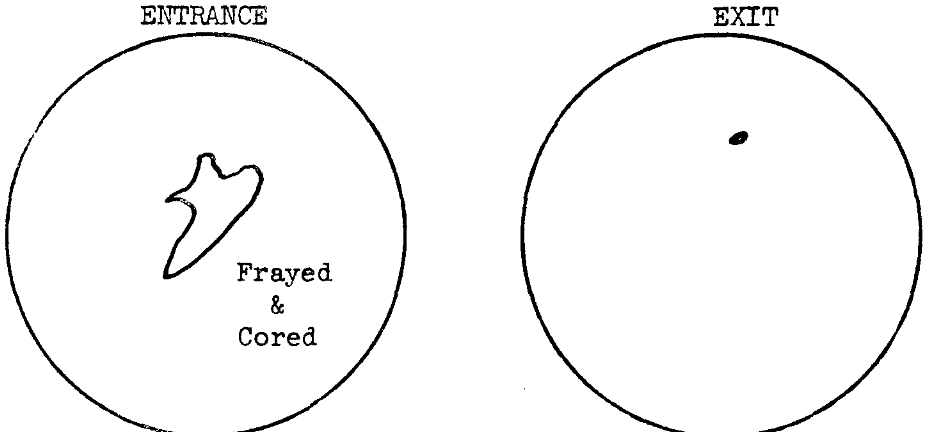
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 28 ROUND NUMBER T 56

DATE FIRED 5 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 1.5 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Gillfab 1075 (.030)

Composite --------------

Self Sealing Uniroyal US-173 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 11 inches below fuel surface.

The skin was cored some with much petaling and cracks. The petals were .25 inches high and rolled over. The backing board was frayed for approximately .5 inches diameter. The self-sealing material was dry with no trace of fuel.

Exit: Tumbled 12 inches below fuel surface.

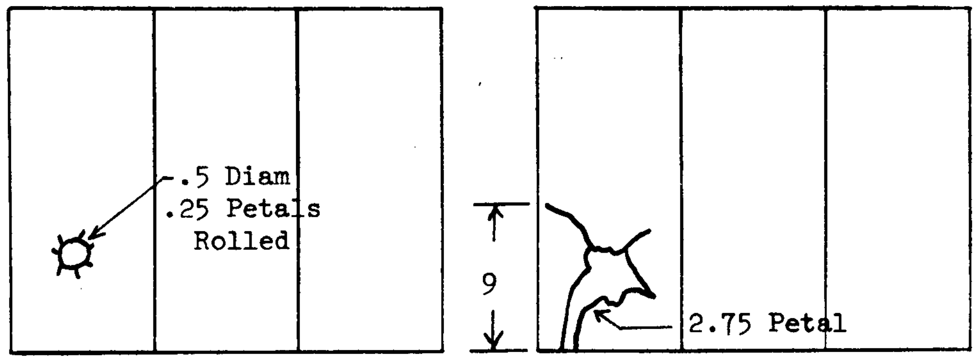
The skin was torn, cored and petaled to 2.75 inches. The backing board was restrained and was torn to pieces (three tears from bottom to top and part missing).

The self-sealing material was pulled into the box and the wound was misaligned thus wound flowed full flow until box emptied. The exit flange was removed and the edges of the wound realigned. The material sealed then with no leakage at 2 psi of Nitrogen. The exit wound would have sealed if supported by the backing board.

BLOCK NUMBER B 28

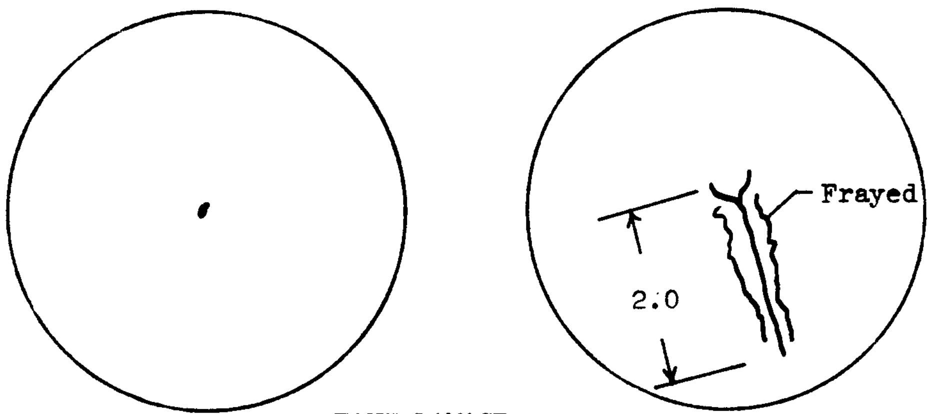
ROUND NUMBER T 56

ENTRANCE *EXIT



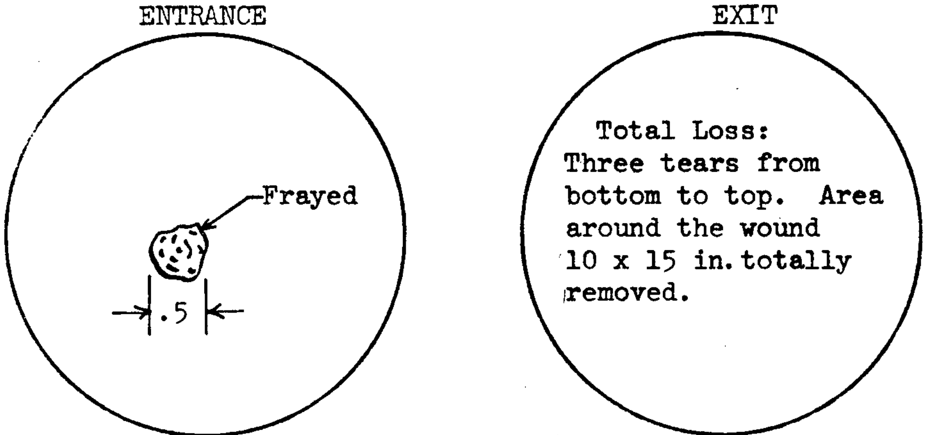
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 28 ROUND NUMBER T 57

DATE FIRED 5 January 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap 1.5 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2899 Ft/Sec

MATERIAL:

Backing Board Gillfab 1075 (.030)

Composite ----------------

Self Sealing Uniroyal US-173 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 11 inches below fuel surface.

The skin was cored and petaled to .25 inches. The backing board was cored and split. The self-sealing material was almost cored but did obtain a damp seal immediately.

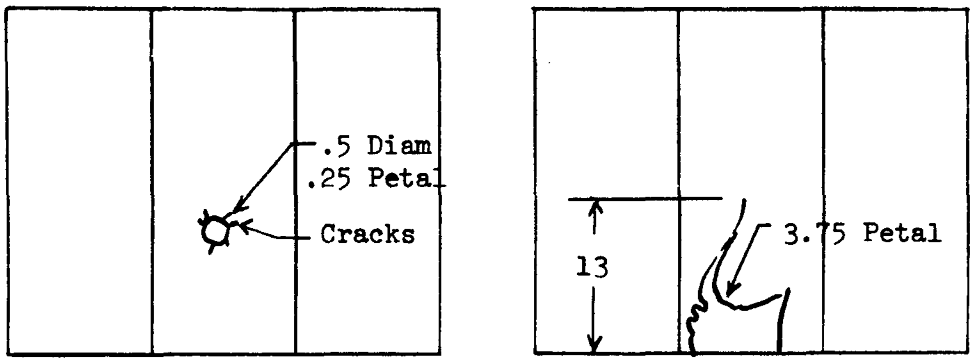
Exit: Tumbled 14 inches below fuel surface.

The skin was cored and petaled to 3.75 inches. The backing board was split, failing totally. Also the backing board was floated in the skin. The failure was very similar to that of the previous shot with the restrained backing board. So no improvement is accomplished by floating the backing board. The self-sealing material wound edges were misaligned, thus no possibility of sealing. The wound would have sealed though, if supported and the wound edges were aligned.

BLOCK NUMBER B 28

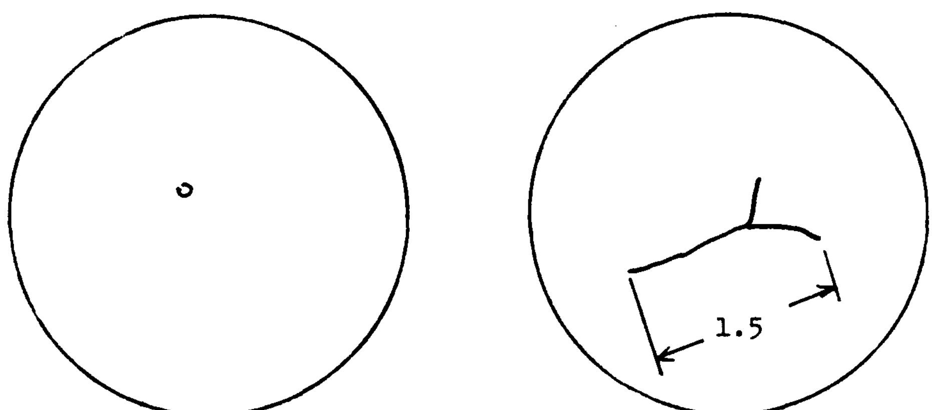
ROUND NUMBER T 57

ENTRANCE *EXIT



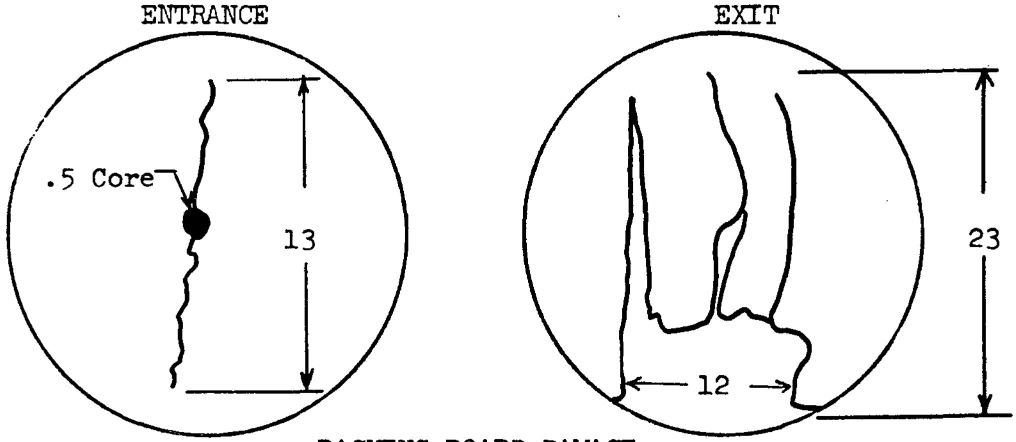
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 30 ROUND NUMBER T 58

DATE FIRED 6 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2899 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ---------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

The skin was cored and had a .4 inches high petal. The backing board was only frayed. The self-sealing material was cracked and supported by the skin petal but obtained a damp seal immediately. The wound leaked enough to only dampen the surfaces; no drips.

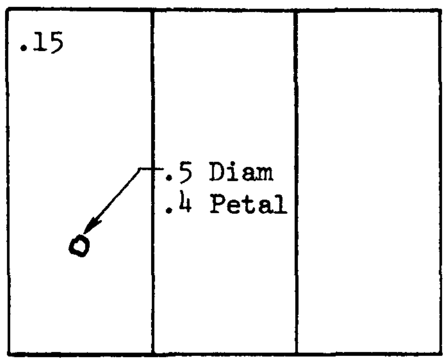
Exit: Tumble (partially) 10 inches below fuel surface.

The skin was cored and petaled to a height of 2.3 inches. The backing board was floated and was only frayed. The self-sealing material was pulled into the box enough to buckle and misalign the edges of the wound thus no seal was possible. The material was cracked badly but only had a 1 1/2 gallon/minute constant leakage rate.

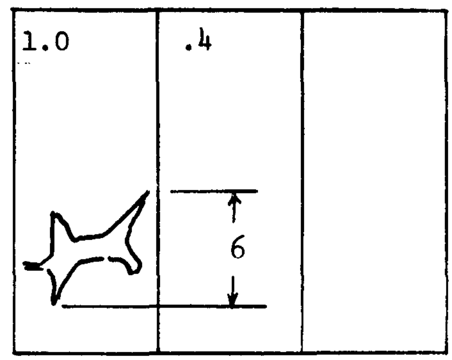
BLOCK NUMBER B 30

ROUND NUMBER T 58

ENTRANCE

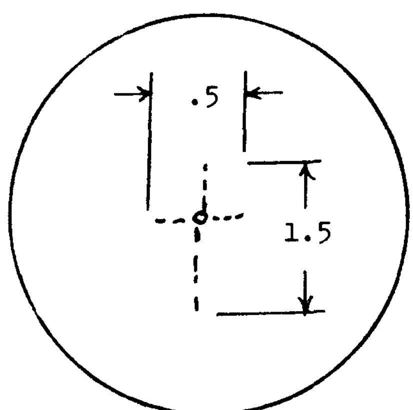


*EXIT

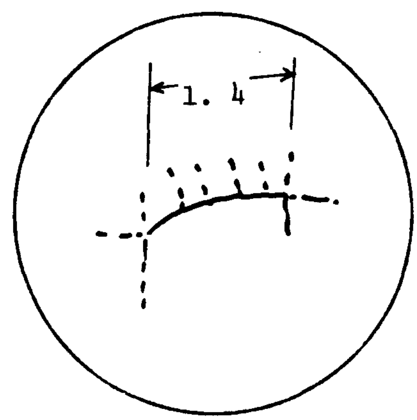


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

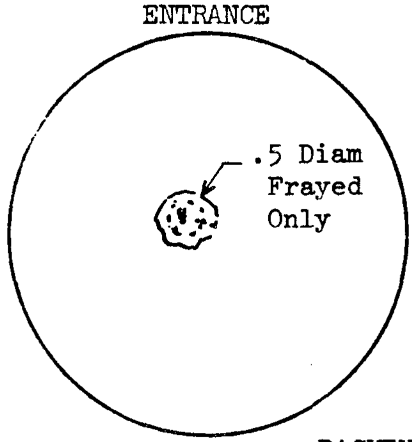


EXIT

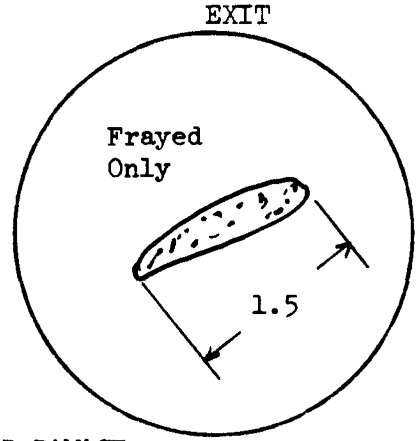


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 30 ROUND NUMBER T 59

DATE FIRED 6 January 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 6061-T6 (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity ------------ Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite -----------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored yes

COMMENTS:

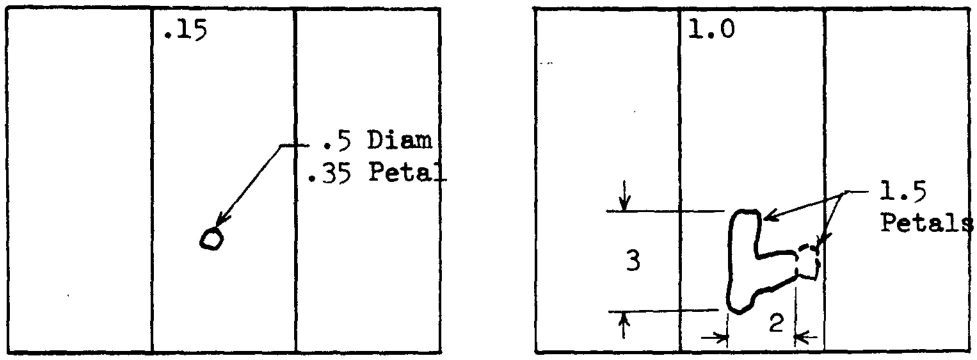
Entrance: Straight 12 inches below fuel surface.
When pressurized to 2 psi, T 58 entrance flowed enough fuel to keep surface damp. The skin was cored and petaled .35 inches. The backing board frayed to the diameter of the projectile. The self-sealing material was damp sealed immediately with some surface wetting occurring.

Exit: Tumble 13 inches below fuel surface.
The skin was cored and petaled to a height of 1.5 inches. The backing board was frayed with very slight coring. The backing board floated. The self-sealing material was split and cored on the fuel side some. The leakage flowed approximately 1/2 the size of a pencil for 1.5 minutes and slowed to a damp seal in 2.5 minutes. Total fuel lost was on the order of 1/4 gallons.

BLOCK NUMBER B 30

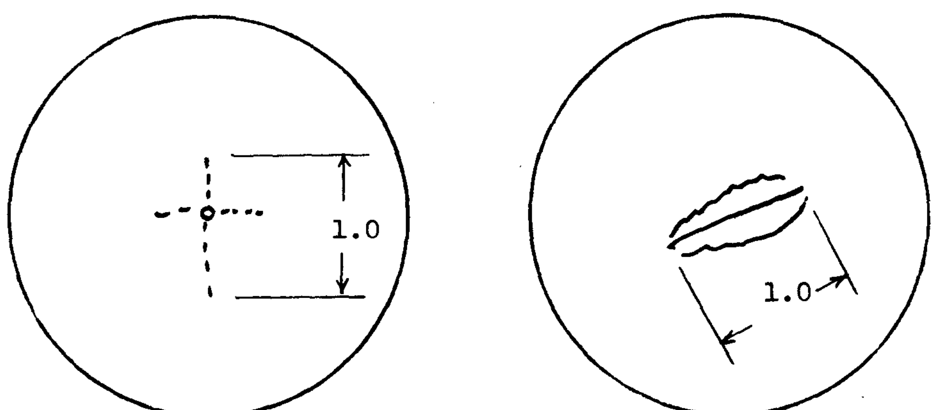
ROUND NUMBER T 59

ENTRANCE *EXIT



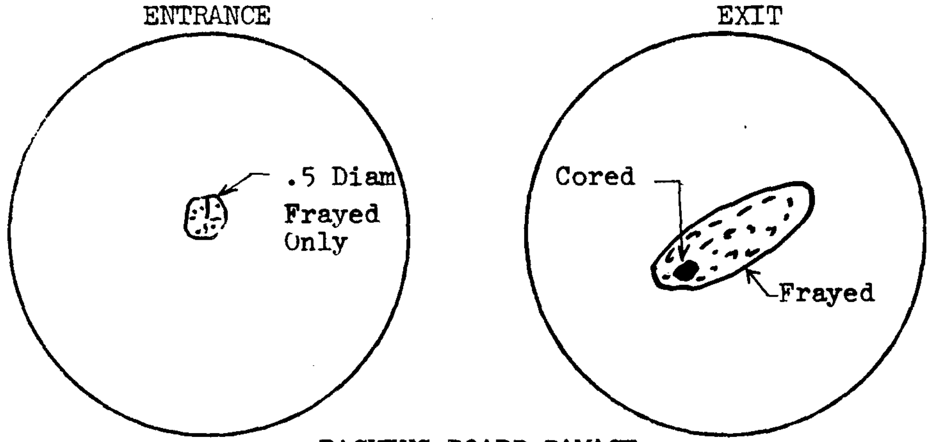
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 30 ROUND NUMBER T 60

DATE FIRED 6 January 1968

TANK CONDITION:

Nitrogen Pressure 1 Psi; Baffling None

Skin Material 6061-T6 (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite --------------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 13 inches below the fuel surface.

The skin cored and petaled .35 inches high. There was no problem of holding the wound open though. The backing board was only frayed to the diameter of the projectile. The self-sealing material flowed fuel for approximately 1 minute before obtaining a damp seal. The leakage quantity was very small.

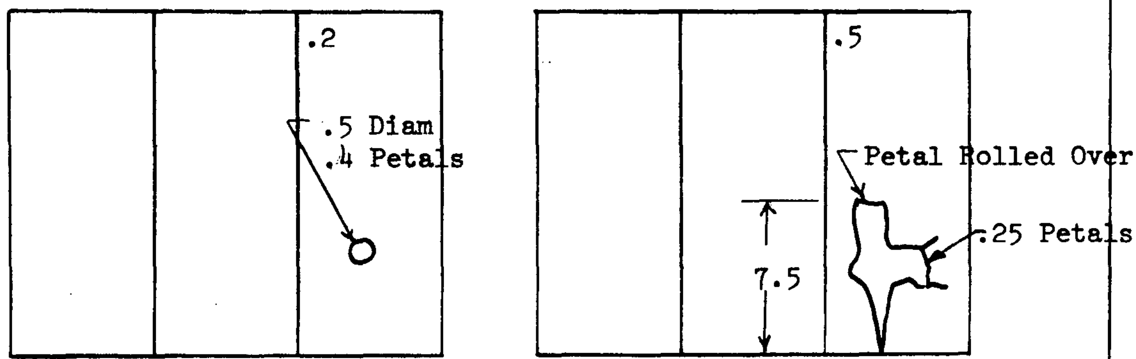
Exit: Part tumbled 14 inches below the fuel surface.

The skin was split and petaled to 1.5 inches high but no coring occured. The backing board on exit side only was floated and was split the length of the projectile with both fraying and coring occurring. However, support was still maintained for the self-sealant material. The self-sealing material was slit and was frayed. The leakage was not measurable but was a fast dripping rate slowing to a damp seal in 2 1/2 minutes.

BLOCK NUMBER B 30

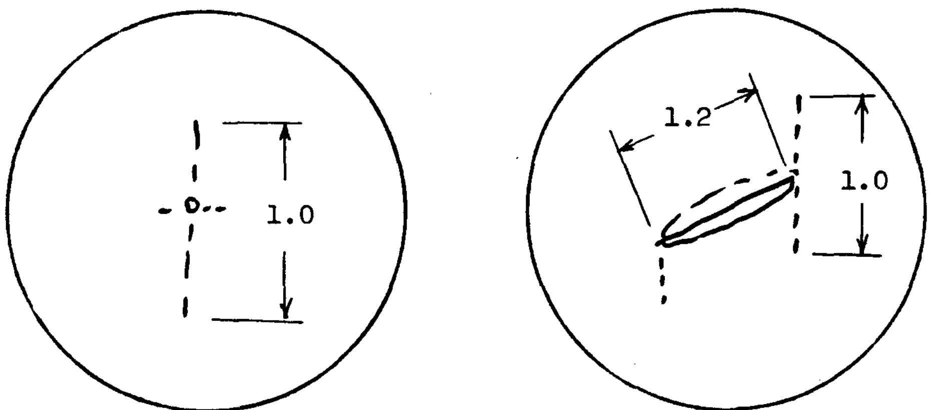
ROUND NUMBER T 60

ENTRANCE *EXIT



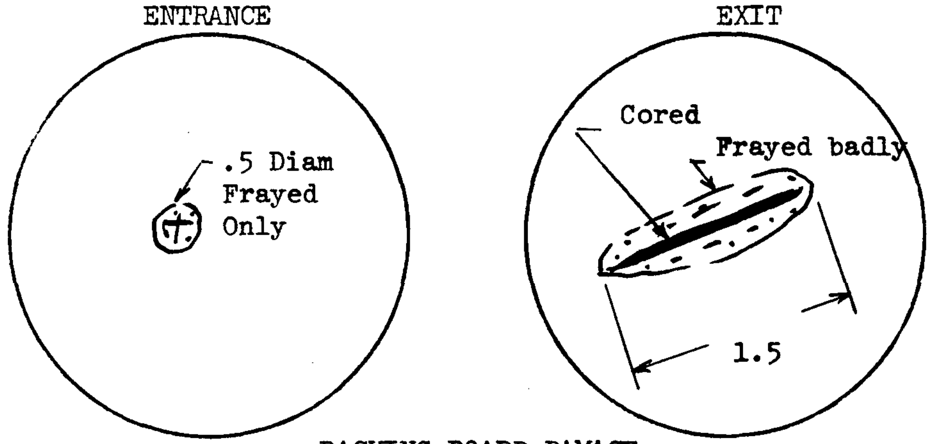
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 30 ROUND NUMBER T 61

DATE FIRED 6 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity 2817 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ----------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal no Exit Seal yes

Entrance Cored yes Exit Cored no

COMMENTS:

Entrance: Fully tumbled 5 inches below fuel surface.

The skin was cored and split. A large flash occured upon impact by projectile. Fuel was noted to spray out through the flash. The backing board was cored to the size of a tumbled projectile. The self-sealing material was slit and cored slightly. The leakage was full flow for approximately 30 seconds and reduced to a rate of 1/4 gallon/minute after 3 minutes.

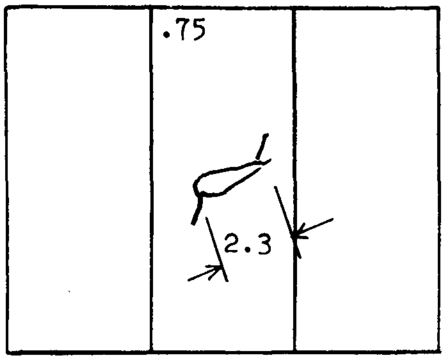
Exit: Partially tumbled 3 inches below the fuel surface.

The skin was petaled but not cored. The backing board was split the length of the projectile with slight fraying. The self-sealing material was dry immediately with no trace of fuel. The projectile nose was found inside the box along with skin and self-sealing material corings when disassembled.

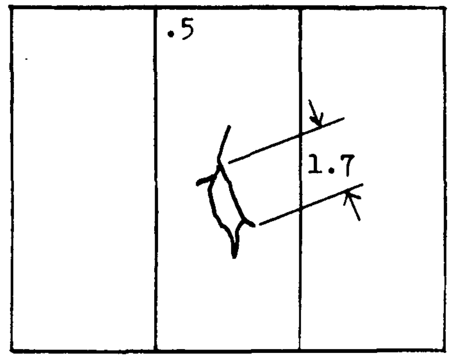
BLOCK NUMBER B 30

ROUND NUMBER T 61

ENTRANCE

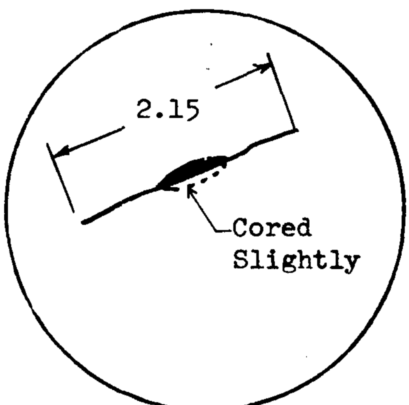


*EXIT

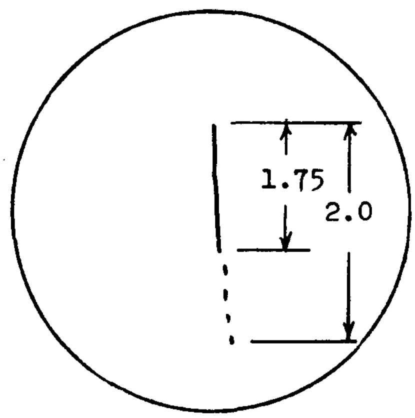


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

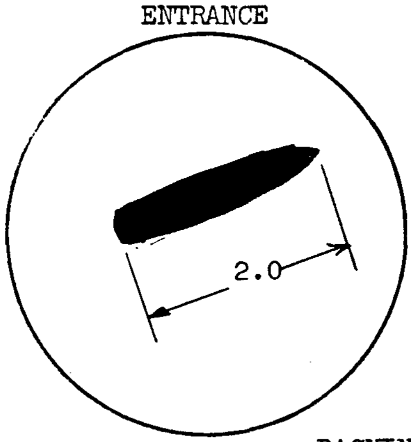


EXIT

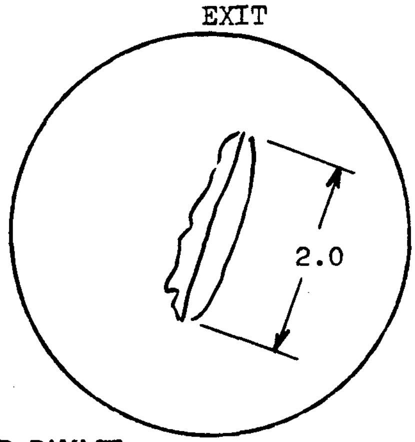


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 32 ROUND NUMBER T 62

DATE FIRED 15 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.040) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2817 Ft/Sec

MATERIAL:

Backing Board Firestone F1-41 (Cal. 50)

Composite ----------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored yes

COMMENTS:

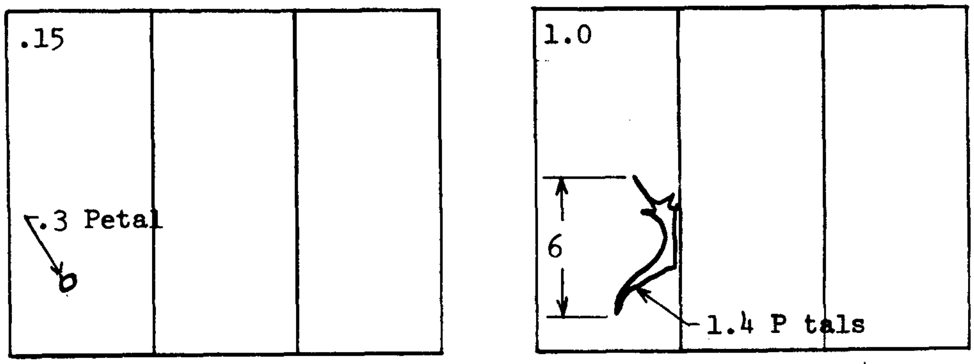
Entrance: Small flash on entrance. Straight 11 inches below fuel surface.
The skin was cored and petaled to .30 inches. However, the petal did not hold wound open. The backing board was only frayed to the size of the projectile. The self-sealing material was cracked but no coring and sealed with only a trace of fuel leakage. The self-sealing material had the impact of the backing board fiber in it from the shock load.

Exit: Fully Tumbled 12 inches below fuel surface.
The skin was petaled 1.4 inches high and cored. The skin also had the imprint of the backing board in it in two panels of the three. Backing board was only frayed. It retained the self-sealing swell. The self-sealing material was cored but was not pulled into the box. Leakage rate was approximately 1/4 - 1/2 gallon/minute.

BLOCK NUMBER B 32

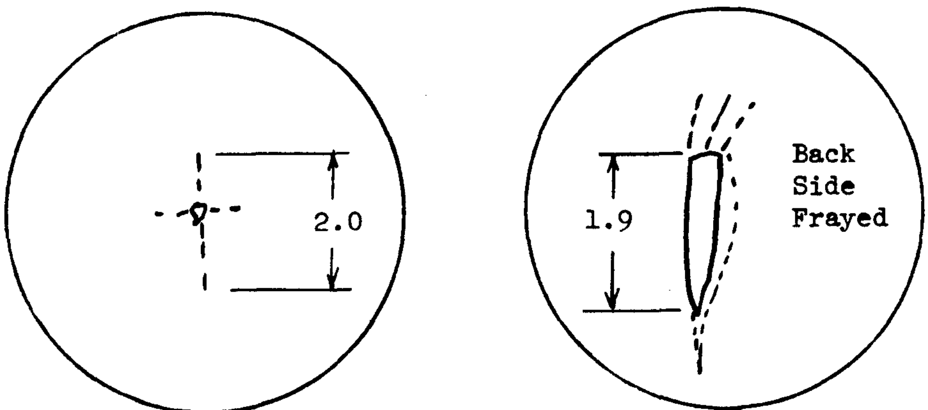
ROUND NUMBER T 62

ENTRANCE | *EXIT



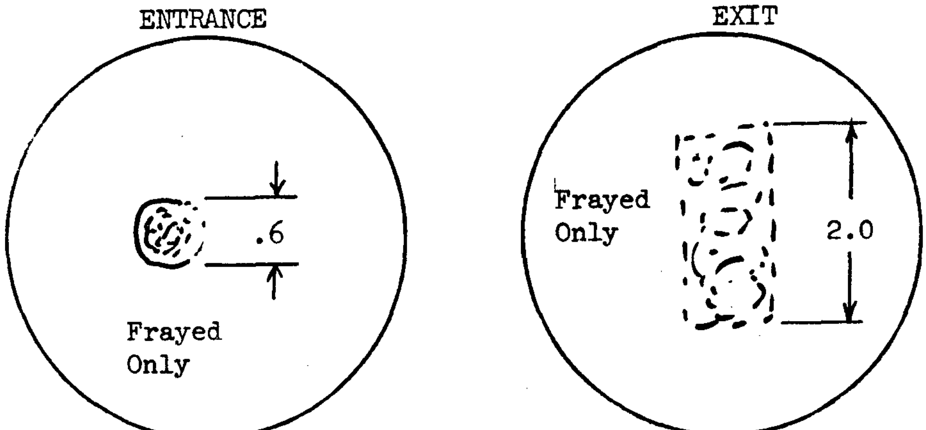
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 31 ROUND NUMBER T 63

DATE FIRED 15 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.040) Skin Gap .5 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Firestone Fl-41 (Cal. 50)

Composite ------------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

The skin was cored and petaled a height of .2 inches; petals rolled also. The backing board was only frayed. The self-sealing material was dry with no trace of leakage. The petaling did not affect the sealing material.

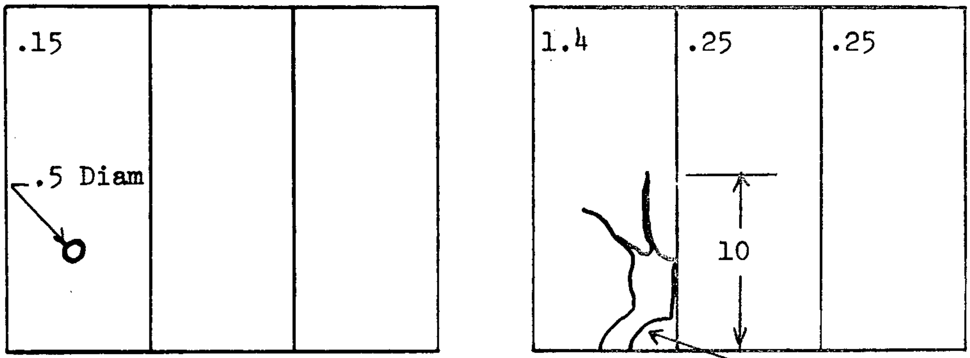
Exit: Tumble 12 inches below fuel surface.

The skin was cored and petaled to 2.8 inches with some rolled over. The backing board was floated and pulled into the skin deflection area thus giving no support to the self-sealing material. The backing board was only frayed at projectile exit. The self-sealing material wound was misaligned from support (was not pulled into box) and could not seal. When opened up and realigned it sealed damp under 2 psi.

BLOCK NUMBER B 31

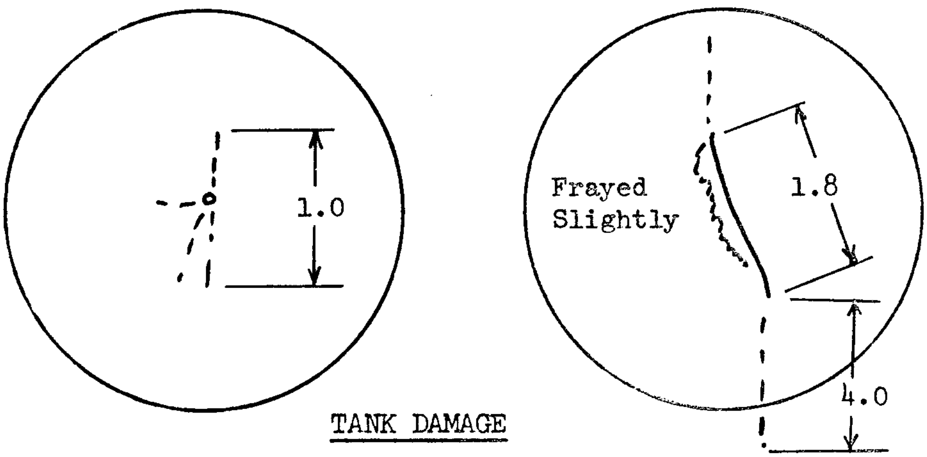
ROUND NUMBER T 63

ENTRANCE | *EXIT



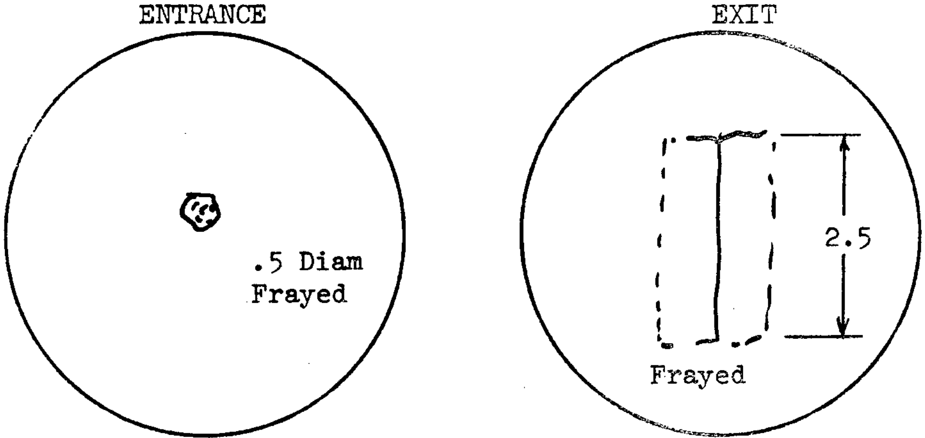
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 31 ROUND NUMBER T 64

DATE FIRED 15 January 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.040) Skin Gap .5 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Firestone F1-41 (Cal. 50)

Composite ---------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

When pressurized exit of T 63 flowed enough to keep surfaces wet.

Entrance: Straight 12 inches below fuel surface.

The skin was petaled .2 inches high with all petals rolled over. The backing board was only frayed to diameter of the projectile. The self-sealing material obtained a damp seal immediately. However, the box lost pressure immediately on impact due to exit side failure.

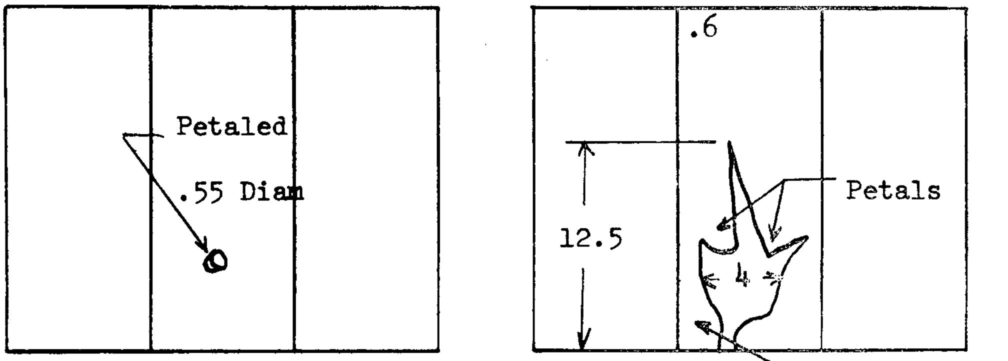
Exit: Tumbled 14 inches below fuel surface.

The skin was cored and petaled 3.5 inches high maximum. The backing board was frayed only in the projectile wound but once again was pulled into the skin deflection area and no support was given to the self-sealing material. The self-sealing material wound was misaligned, thus no seal was possible. The leakage rate was 5 gallon+/minute at zero pressure.

BLOCK NUMBER B 31

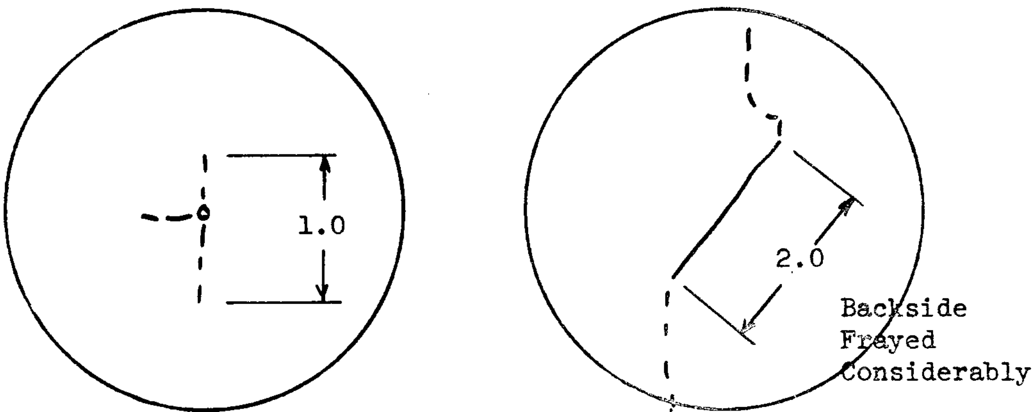
ROUND NUMBER T 64

ENTRANCE | *EXIT



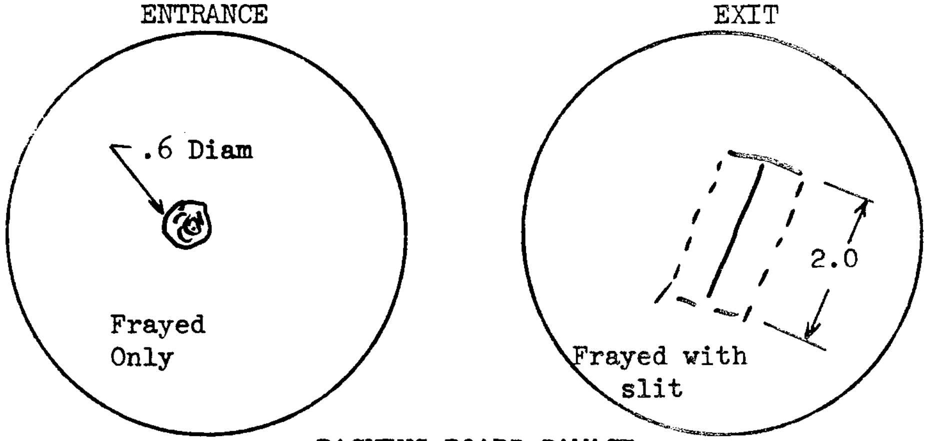
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 37 ROUND NUMBER T 65

DATE FIRED 15 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 6061-T6 (.080) Skin Gap 1.25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2963 Ft/Sec

MATERIAL:

Backing Board Gillfab 1068 (Cal. 50)

Composite ---------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

Skin flashed as it was impacted by projectile. The skin was cored and petaled 0.4 inches maximum. Backing board was cored and frayed to size of projectile. The self-sealing material sealed damp immediately with only a trace of fuel leakage.

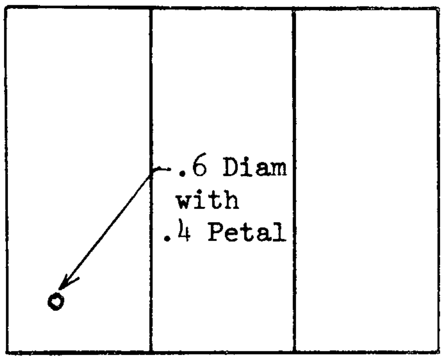
Exit: Tumble 16 inches below fuel surface.

The skin cored and petaled greatly. Some petaling rolled over slightly. The backing board total failure with 3 splits from top to bottom with other smaller tears. The self-sealing material would not seal without support from a scale and leaked constantly, with zero pressure, at 1-2 gallon/minute. The failure was due to the backing board failing.

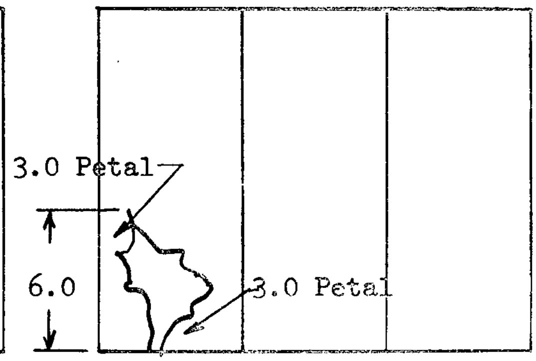
BLOCK NUMBER B 37

ROUND NUMBER T 65

ENTRANCE

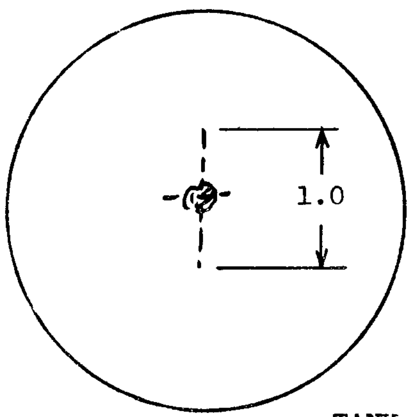


*EXIT

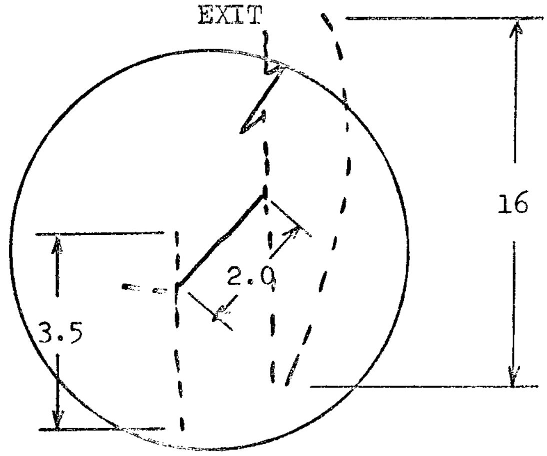


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

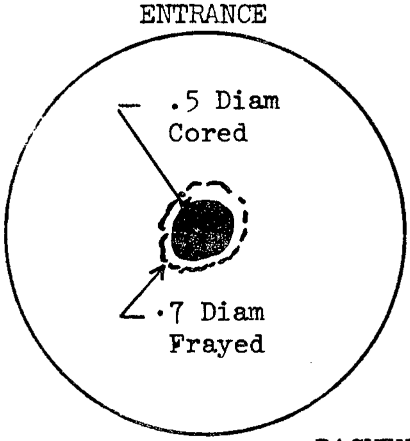


EXIT

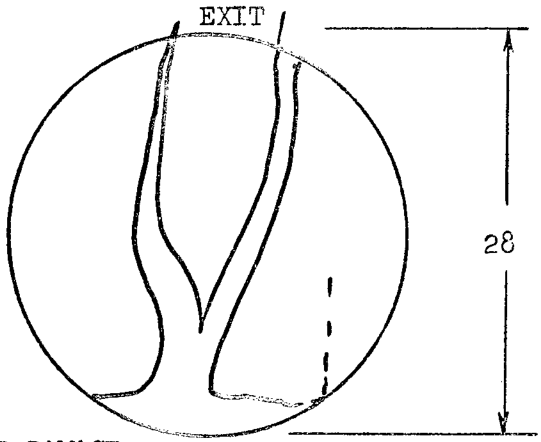


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 39 ROUND NUMBER T 66

DATE FIRED 16 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.040) Skin Gap 1.25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2899 Ft/Sec

MATERIAL:

Backing Board Conolite B33 FGIW (Cal. 50)

Composite ------------------

Self Sealing Goodyear Tire DX-325 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches below fuel surface.

The skin was cored and petaled. The backing board was just frayed to diameter of projectile. The self-sealing material sealed dry immediately with no trace of fuel leakage.

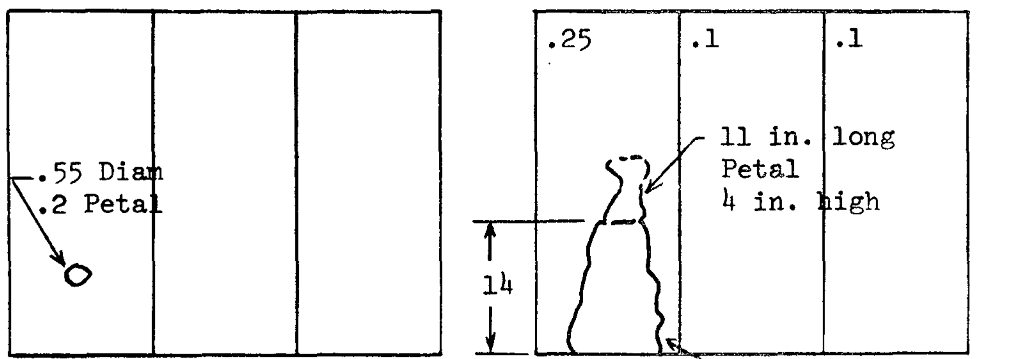
Exit: Straight but base forward 12 inches below fuel surface.

The skin was cored and petaled. One petal was 11 inches long and rolled over so that it was only 4 inches high. The backing board was torn 13 inches long and 4 inches across with some coring. The self-sealing material was torn 13 inches long and 4 inches across, but was not cored. Some fraying was present in the cloth. The self-sealant was well activated. The tank was emptied in approximately 2 minutes. Leakage was photographed at 2 minutes. Leakage rate was approximately 25 gallon/minute.

BLOCK NUMBER B 39

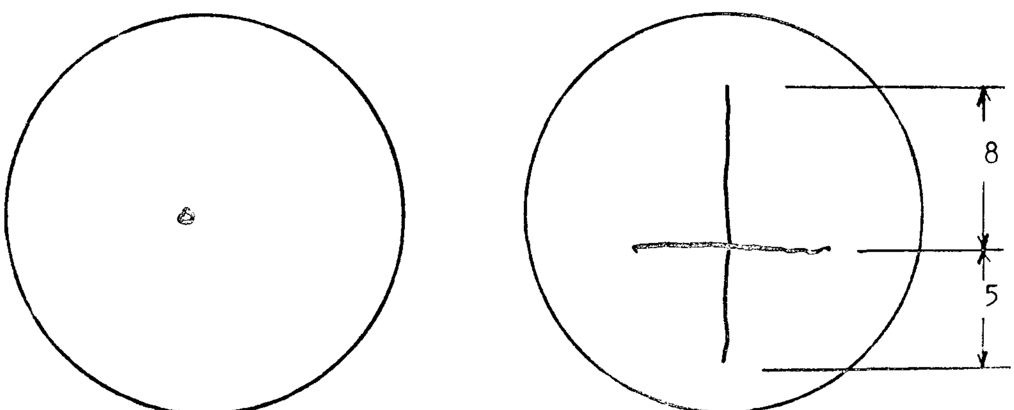
ROUND NUMBER T 66

ENTRANCE | *EXIT



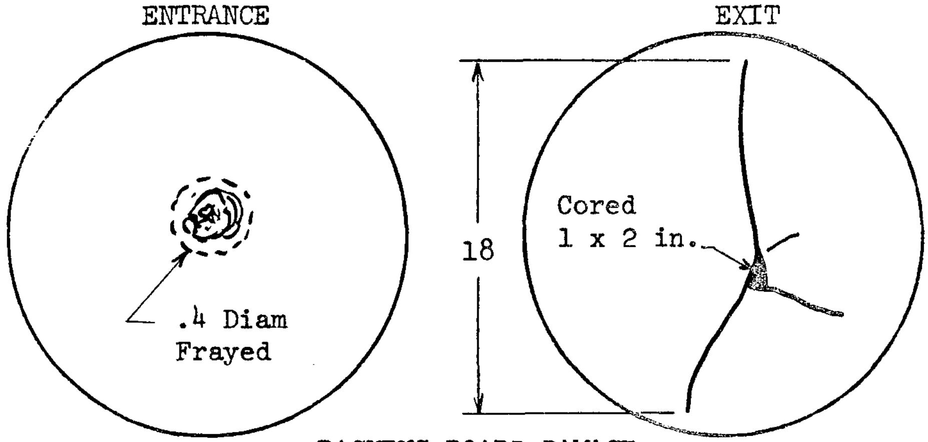
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 40 ROUND NUMBER T 67

DATE FIRED 16 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.040) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2920 Ft/Sec

MATERIAL:

Backing Board Goodyear Aero ARM 1800 (Cal. .50)

Composite ---------------

Self Sealing Uniroyal US-182 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored yes

COMMENTS:

Entrance: Straight 12 inches below fuel surface. Flash on entry.

The skin was cored with only a small amount of petaling. The backing board was only frayed. The self-sealing material was dry immediately with no trace of fuel on the surfaces.

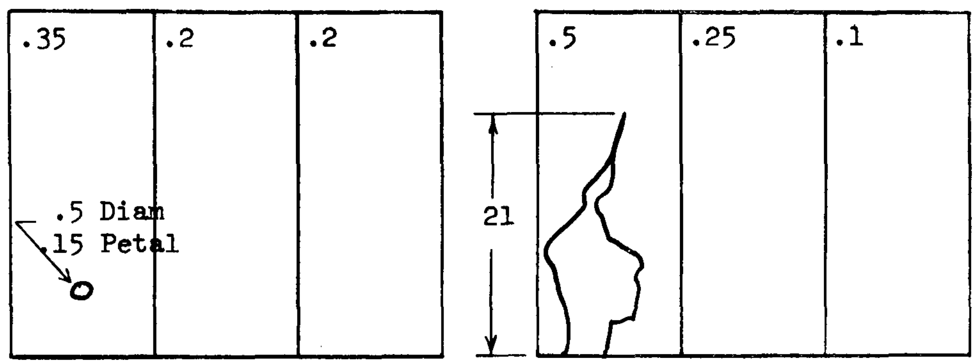
Exit: Tumbled 11 inches below fuel surface.

The skin was cored, petaled and split out giving no support to the backing board. The backing board fiber was split but the ARM material was intact. The self-sealing material was split, frayed and cored slightly. The backing board and self-sealer was misaligned. If this had not happened the material might have sealed. Leakage rate was 2-3 gallon/minute.

BLOCK NUMBER B 40

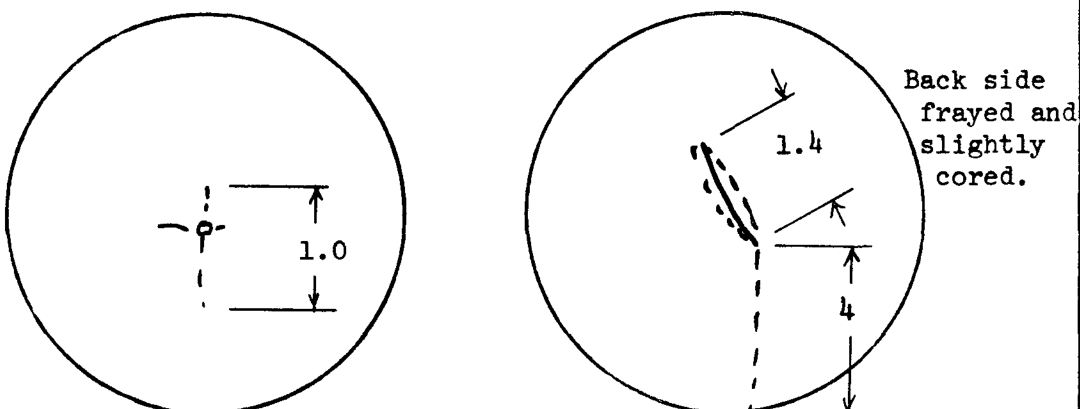
ROUND NUMBER T 67

ENTRANCE *EXIT



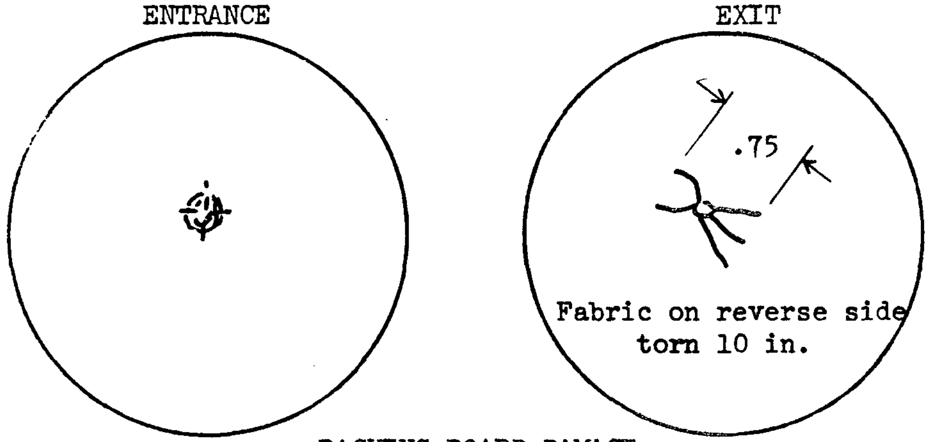
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 43 ROUND NUMBER T 68

DATE FIRED 17 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ------------------

Self Sealing Goodyear Tire DX 325 (cal .50) Entrance Side
Firestone 1146 (cal .50) Exit Side

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored (SS)

COMMENTS:

Entrance: Straight 13 inches below fuel surface.

The skin **flashed** as it was impacted by the projectile and was cored with slight petaling. The backing board was just frayed. The self-sealing material sealed dry with only a trace of fuel leaking out at impact.

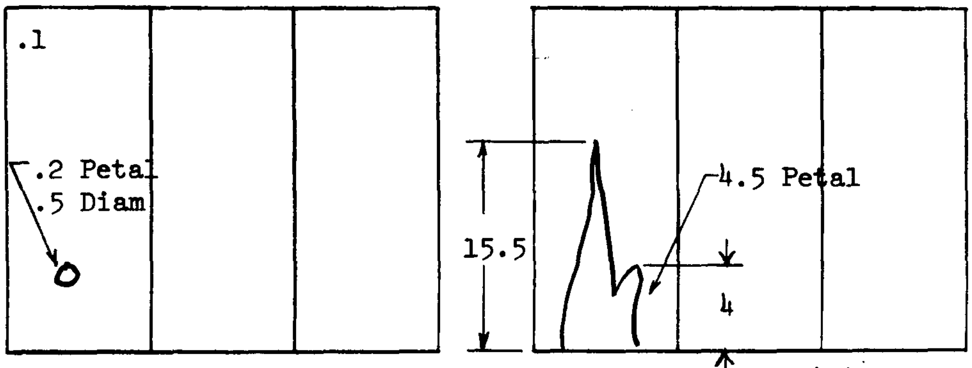
Exit: Tumbled 15.5 inches below fuel surface.

The skin was split with coring and petaling occurring. The backing board was frayed and torn up when it pulled into the box. The self-sealing material was cored slightly on the back side from the projectile but it was determined that it would have sealed. However, the edge of the material where the thickness changed to the flange edging was torn off and the flange edging was also cut by the weld bead on the flange.

BLOCK NUMBER B 43

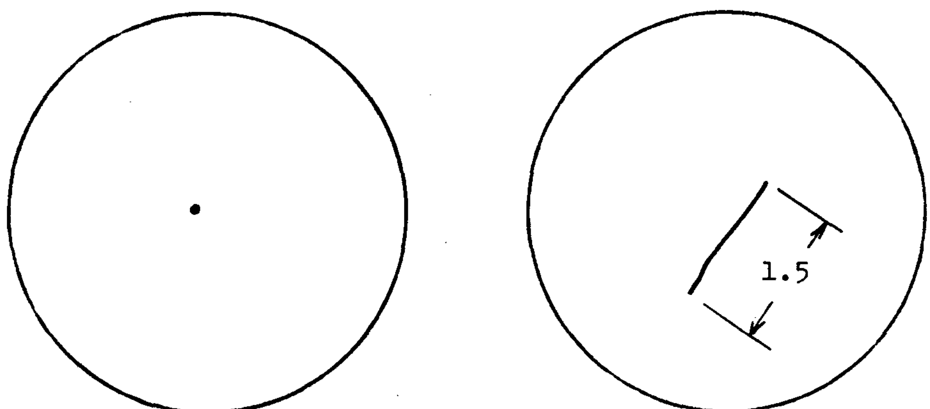
ROUND NUMBER T 68

ENTRANCE *EXIT



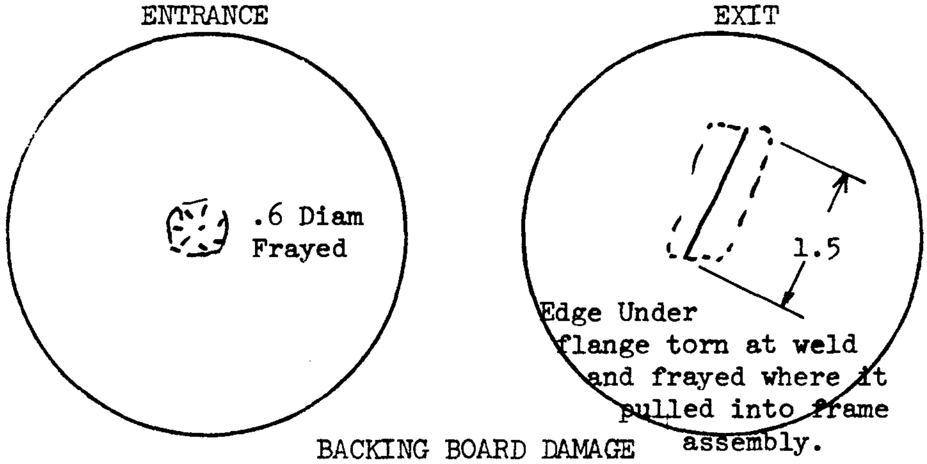
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 43 ROUND NUMBER T 69

DATE FIRED 17 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2963 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ----------------

Self Sealing Goodyear Tire DX-325 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12.5 inches fuel head.

The skin flashed as it was impacted. The backing board frayed with a very small amount of coring. The self-sealing material was damp immediately with only the surface dampened.

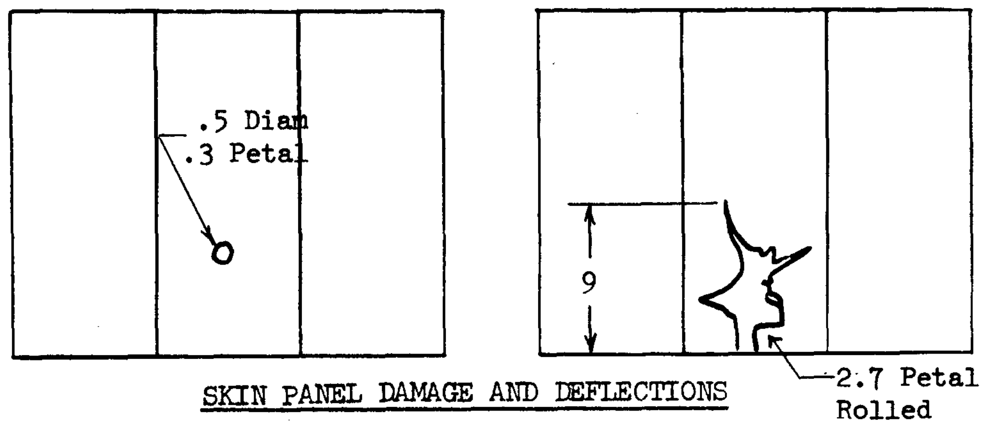
Exit: Tumbled 13 inches fuel head.

The skin was cored very little but was petaled badly. The backing board was frayed to the point that some support was lost. The self-sealing material sealed, though, with only dripping immediately and that stopped in two minutes.

BLOCK NUMBER B 43

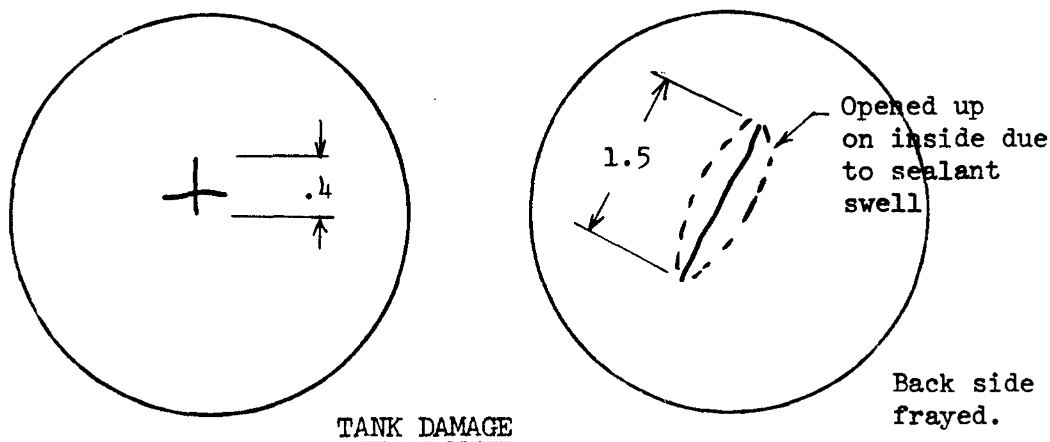
ROUND NUMBER T 69

ENTRANCE *EXIT



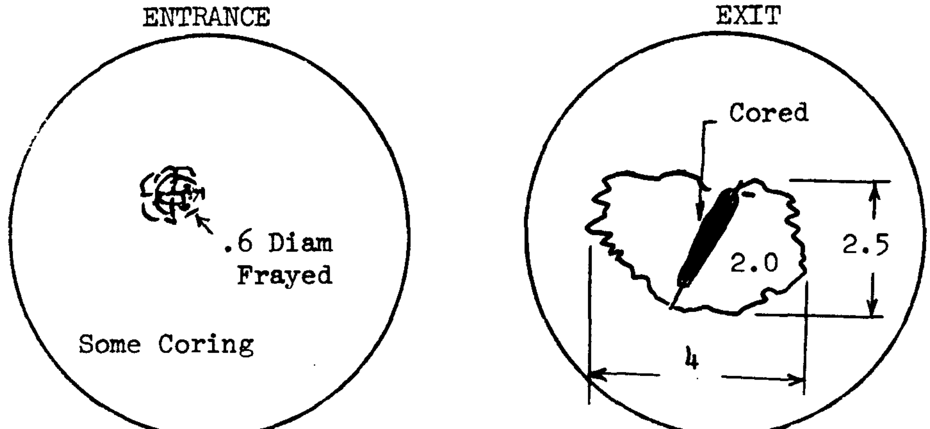
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 43 ROUND NUMBER T 70

DATE FIRED 17 January 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2985 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ---------------

Self Sealing Goodyear Tire DX-325 (Cal. 50)

RESULTS:

Entrance Seal yes (when pressure decreased to 0 psi) Exit Seal yes (when pressure decreased to 0 psi)

Entrance Cored no Exit Cored no

COMMENTS:

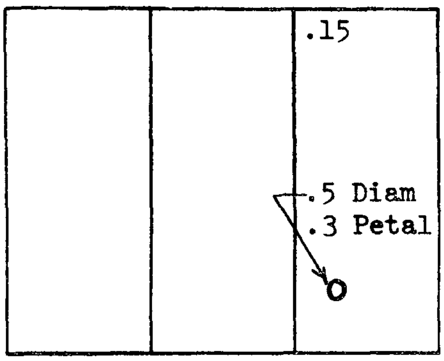
Entrance: Flash observed. Straight 13 inches fuel head.
The skin cored with some petaling. The backing board frayed. The self-sealing material sprayed a small stream slowing to a trickle in 2 minutes at 2 psi. The wound dried when pressure was decreased to zero at time = 3.5 minutes.

Exit: Tumbled 14 inches below fuel surface.
The skin petaled with a very small amount of coring. The petals rolled over and the backing board frayed and cored. The self-sealing material leaked at a constant trickle until the pressure was reduced to zero. The wound then dried.
The exit wound of T 69 flowed 150-250 ml /minute when pressured to 2 psi, and stayed damp after the T 70 round at zero pressure.

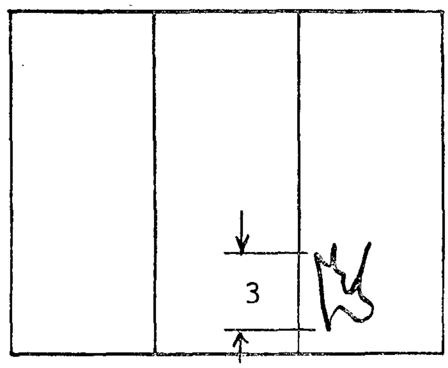
BLOCK NUMBER B 43

ROUND NUMBER T 70

ENTRANCE

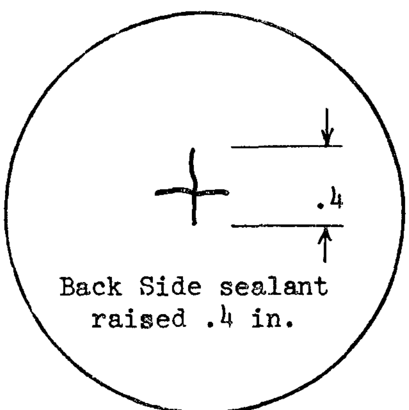


*EXIT

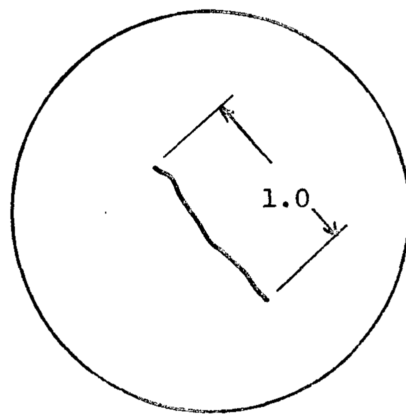


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE



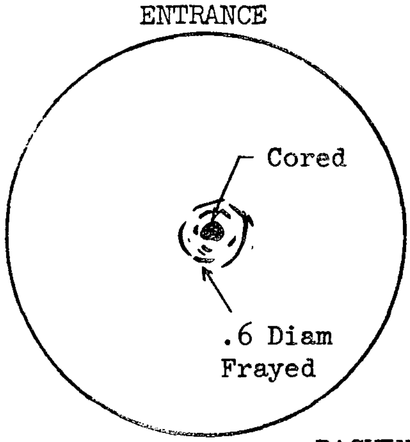
EXIT



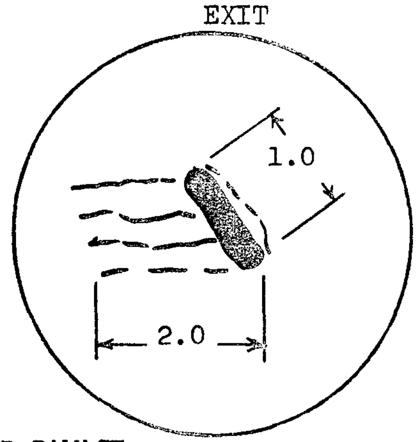
Back Side
Frayed

TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 43 ROUND NUMBER T 71

DATE FIRED 17 January 1968

TANK CONDITION:

Nitrogen Pressure 0 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity 2759 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite ---------------

Self Sealing Goodyear Tire DX-325 (Cal. 50)

RESULTS:

Entrance Seal yes (3 minute trickle) Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

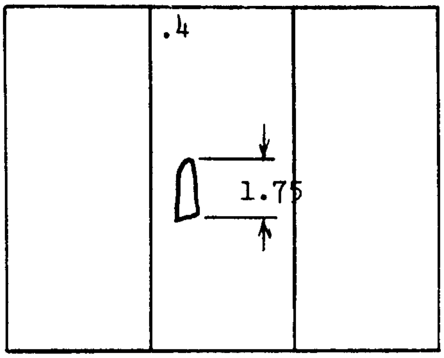
Entrance: Tumbled 61 inches below fuel surface. Flash observed on skin. The skin cored with no petaling. The backing board frayed and cored. The self-sealing material leaked a small stream 1/4-1/2 gallon/minute slowing to a trickle in 3 minutes.

Exit: Partial tumbled base forward direction 5 inches fuel head. The skin only petaled with no coring.. The backing board was frayed. The self-sealing material obtained a damp seal immediately. The exit wound of T 69 was opened up when the sealant was knocked out of the wound. Had to provide support for T 69 exit to continue test and reseal front flange.

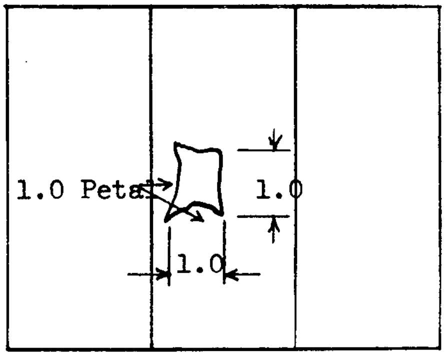
BLOCK NUMBER B 43

ROUND NUMBER T 71

ENTRANCE

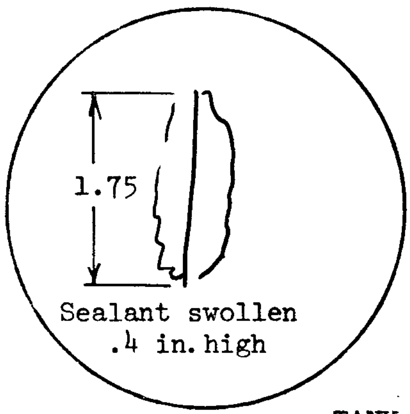


*EXIT

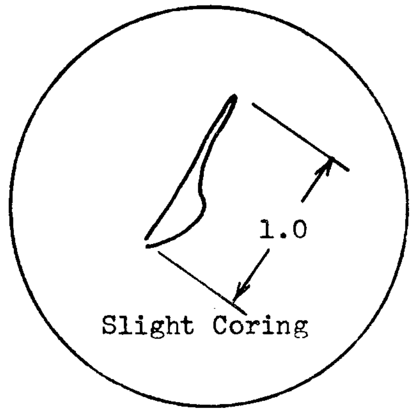


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE



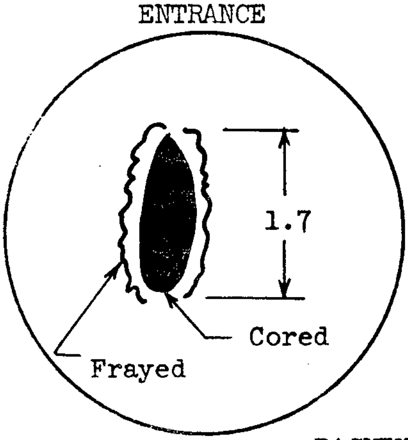
EXIT



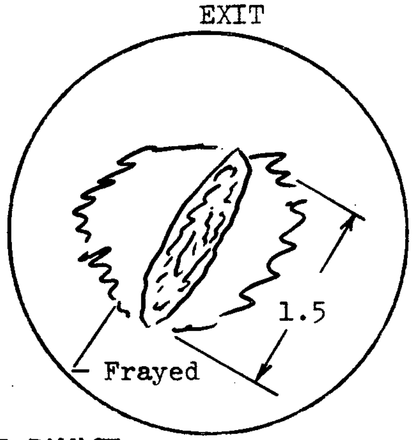
Back Side
Sealant
raised
.4 in.

TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 43 ROUND NUMBER T 72

DATE FIRED 17 January 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.080) Skin Gap 0 in.

PROJECTILE:

Caliber 50 Type AP Entry Tumbled

Velocity 2920 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-41 (Cal. 50)

Composite --------------

Self Sealing Goodyear Tire DX-325 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Observed flash on entrance. Projectile failed to tumble. Impacted below 5 inches fuel.

The skin was cored with no petaling. The backing board frayed with small core. The self-sealing material flowed a stream for only 30 seconds, then slowed to a trickle.

Exit: Full tumble 4.5 inches fuel head.

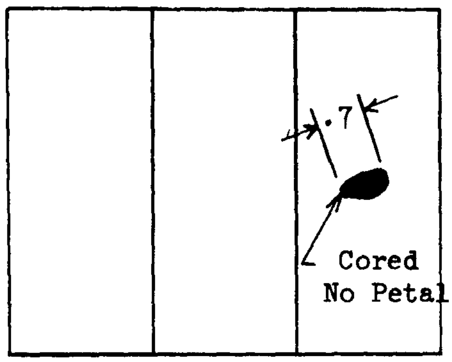
The skin was cored and petaled to 1.75 inches high. The projectile exited next to a wood support and struck the steel support angle. The backing board frayed. The self-sealing material was misaligned so no seal was accomplished. After 2 minutes the leakage was constant at 1.5 gallon/minute under 2 psi. When the pressure was reduced to zero the leakage slowed to just a trickle. The projectile impact opened exit wounds T 70, T 71, T 69, entrance T 71 damp.

On disassembly of box, found brass, aluminum, and some self-sealing inside.

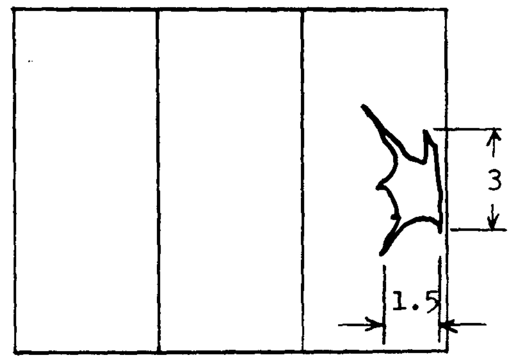
BLOCK NUMBER B 43

ROUND NUMBER T 72

ENTRANCE

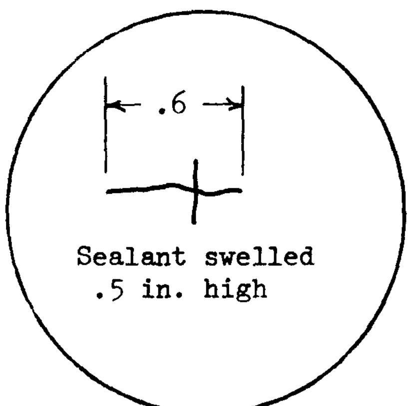


*EXIT

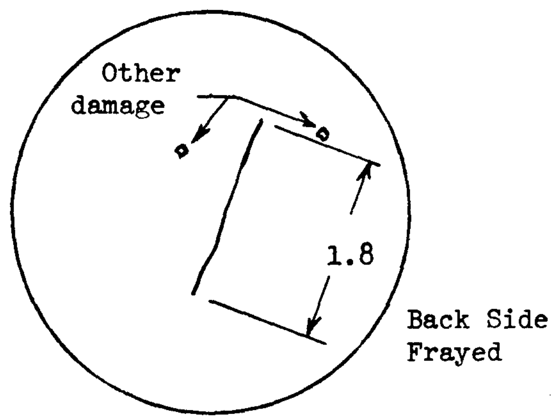


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

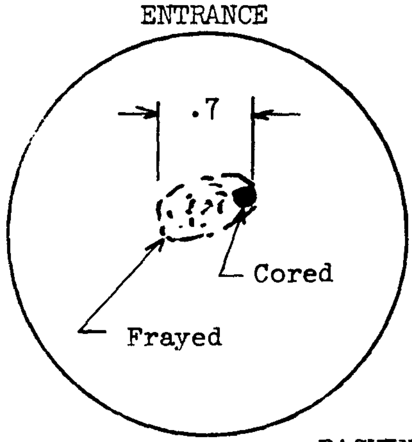


EXIT

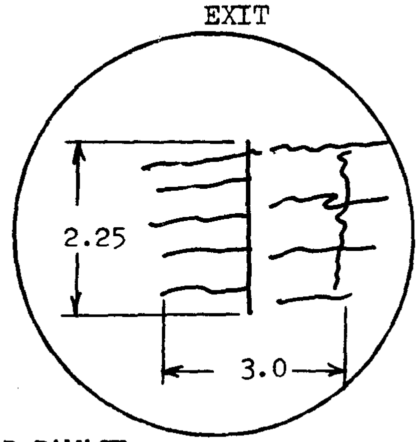


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 51 ROUND NUMBER T 73

DATE FIRED 27 February 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2632 Ft/Sec

MATERIAL:

Backing Board Conolite B33 FGIW (Cal. 50)

Composite ---------------

Self Sealing Uniroyal US-179 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal no (Seeped)

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 11.5 inches high.

The skin was cored .30 diameter and was petaled .2 inches high. The backing board was frayed .35 diameter. The self-sealing material suffered no damage and sealed damp immediately. Only a trace of fuel was present on the backing board.

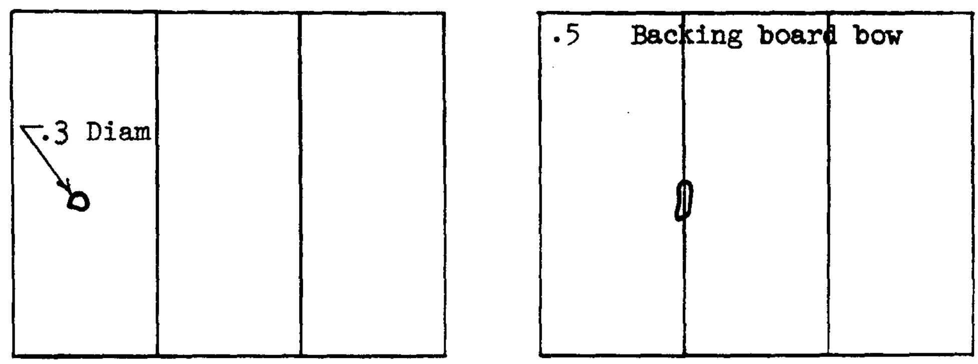
Exit: Tumble 10 inches high.

The round hit the wood support and buried 1/4 inches deep. No skin was installed on exit side of the tank. Backing board deflected .5 inches and was frayed the size of the tumbled projectile. The self-sealing material slit and leaked a stream from the wound (dripping from structure) and slowed some in two minutes. Pressure was reduced to zero after 3 minutes; the wound sealed damp. When repressured, the wound seeped constantly in fast drips. The exit wound was slightly misaligned and would have been classed as a reduced rate leak.

BLOCK NUMBER B 51

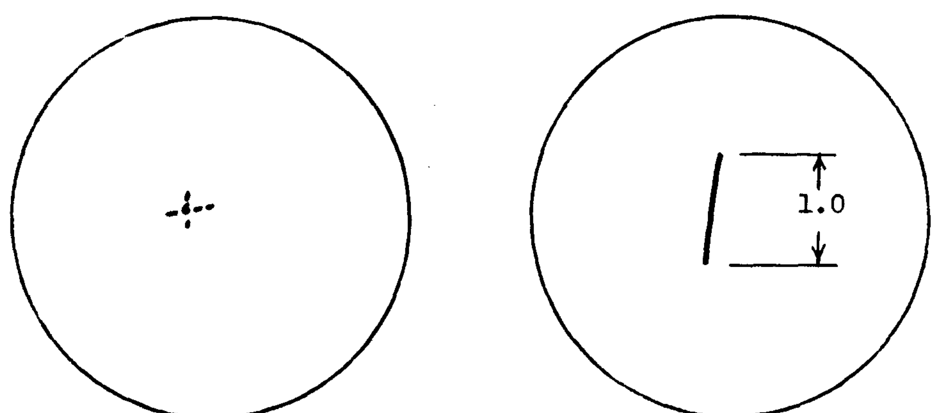
ROUND NUMBER T 73

ENTRANCE *EXIT



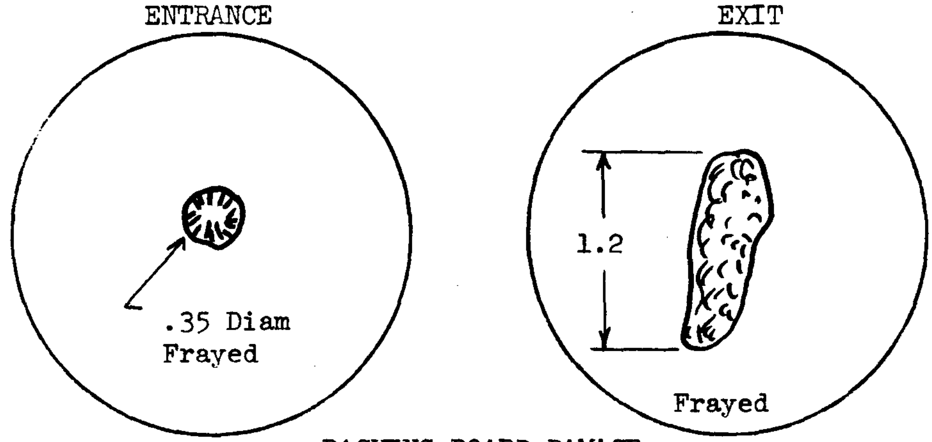
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 51 ROUND NUMBER T 74

DATE FIRED 27 February 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 2024-T3 Clad (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity -------------- Ft/Sec

MATERIAL:

Backing Board Conolite B33 FGIW (Cal. 50)

Composite --------------

Self Sealing Uniroyal US-179

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: Full tumble. 4.5 inches high.

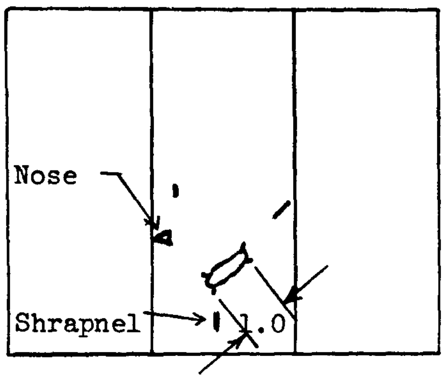
The projectile broke up and the nose and another piece entered the cell separately. The skin was cored (Petals .2 inches) and the backing board frayed badly with slight coring. The self-sealing material was slit and leaked a stream the size of a pencil lead for 2 minutes 15 seconds before obtaining a damp seal at 2 psi. At 3 1/2 minutes, pressure was taken to zero and the wound sealed dry. Total leakage did not exceed 1/2 gallon.

Exit: Round struck the self-sealing material and just marked it. No damage; no exit.

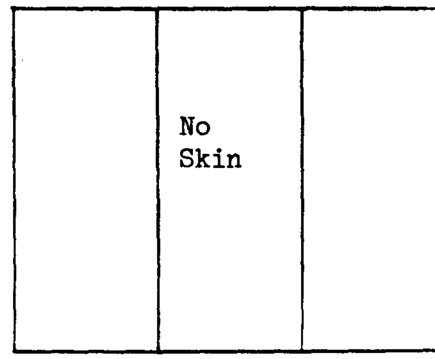
BLOCK NUMBER B 51

ROUND NUMBER T 74

ENTRANCE

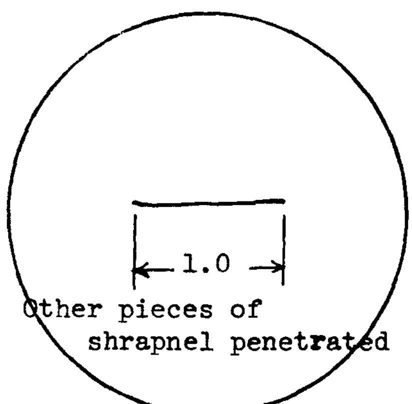


*EXIT

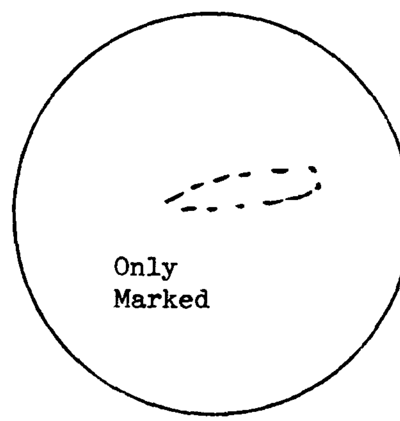


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

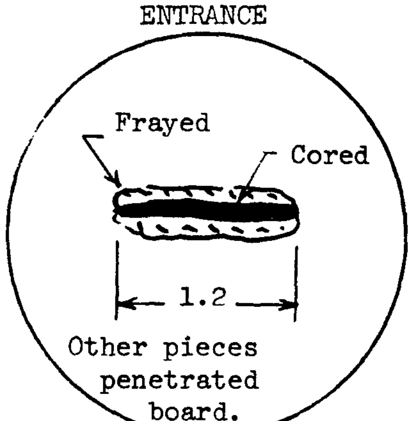


EXIT

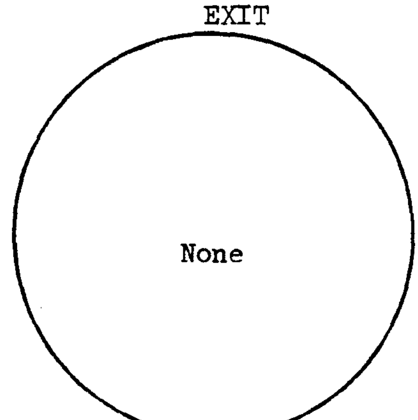


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 51.1 ROUND NUMBER T 75

DATE FIRED 27 February 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Orange foam

Skin Material 2024-T3 Clad (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type API Entry Straight

Velocity 2685 Before striker plate Ft/Sec

MATERIAL:

Backing Board Conolite B33 FGIW (Cal. 50)

Composite ------------------

Self Sealing Uniroyal US-179

RESULTS:

Entrance Seal yes Exit Seal No exit

Entrance Cored no Exit Cored N.A.

COMMENTS:

Entrance: Straight 6 inches high. 12 inches below fuel.

The API projectile struck the striker (.020 2024-0 alum) 18 inches in front of the cell. All witnesses saw a flash. The skin was cored and petaled .15 inches high. The backing board was frayed only the size of the projectile. The self-sealing material sealed dry with only a trace of fuel on the backing board.

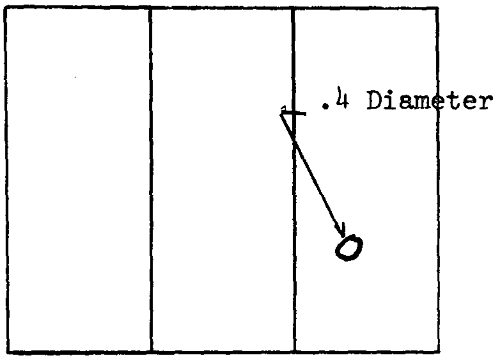
Exit: None.

The projectile traveled through the foam striking the rear self-sealing material (cutting it slightly) then bounced back into the foam approximately 4 inches. No other damage or leakage occurred.

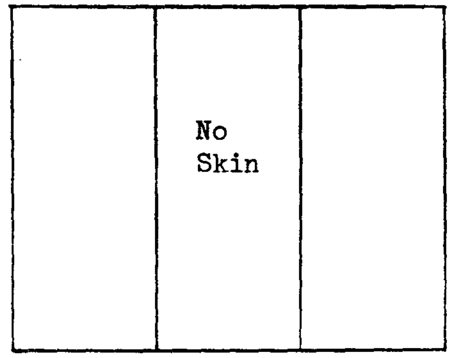
BLOCK NUMBER B 51.1

ROUND NUMBER T 75

ENTRANCE

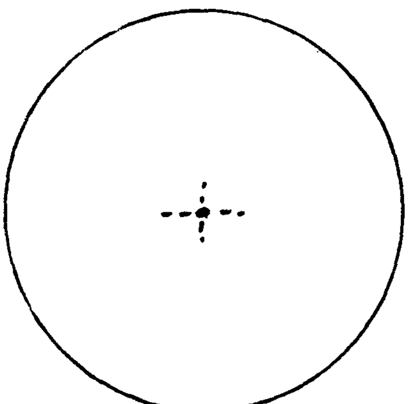


*EXIT

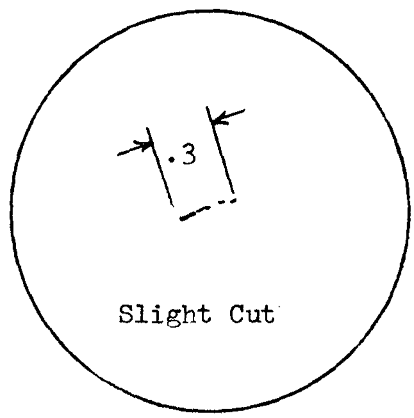


SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE

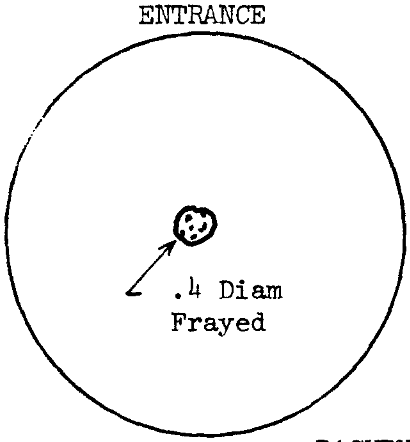


EXIT

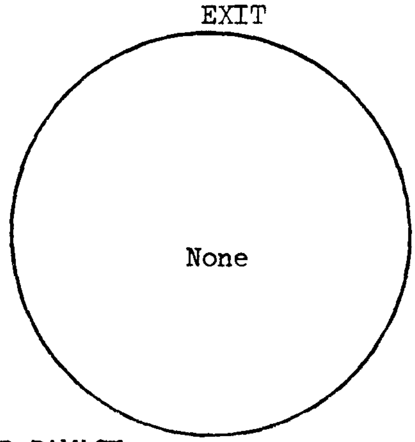


TANK DAMAGE

ENTRANCE



EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 53 ROUND NUMBER T 76

DATE FIRED 27 February 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Orange foam

Skin Material 6061-T6 (.080) Skin Gap .75 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2597 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite ----------------

Self Sealing Goodyear Tire FTL-13 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 12 inches high. 6 inches fuel head.

The skin was cored and petaled, both inward and outward. Highest .2 inches. The backing board was frayed the size of the projectile. The self-sealing material sealed dry with a very small trace of fuel.

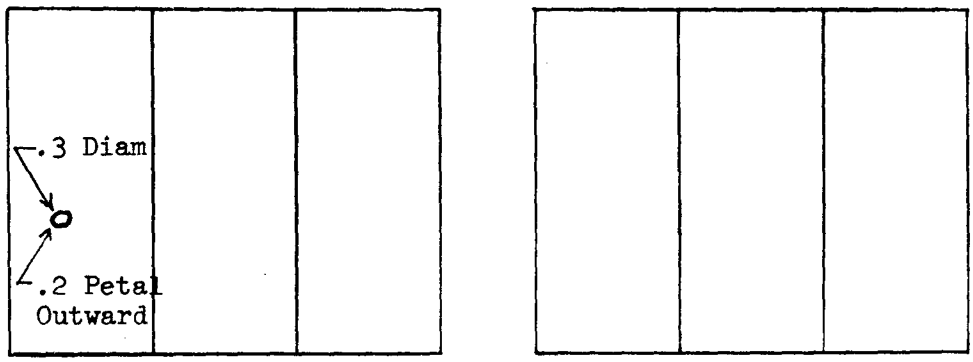
Exit: Partial tumbled. 9 inches high.

No skin was installed on exit side. The backing board was frayed but no deflection occurred. The self-sealing material was slit with the wound misaligned. No seal occurred. The leakage was a stream about half the size of a pencil and would not slow in 3 minutes with 2 psi pressure. Reduced pressure to zero; leakage continued to flow down surface instead of spraying out. Classed as wound failure; Reduced Rate Leakage. Material misaligned some.

BLOCK NUMBER B 53

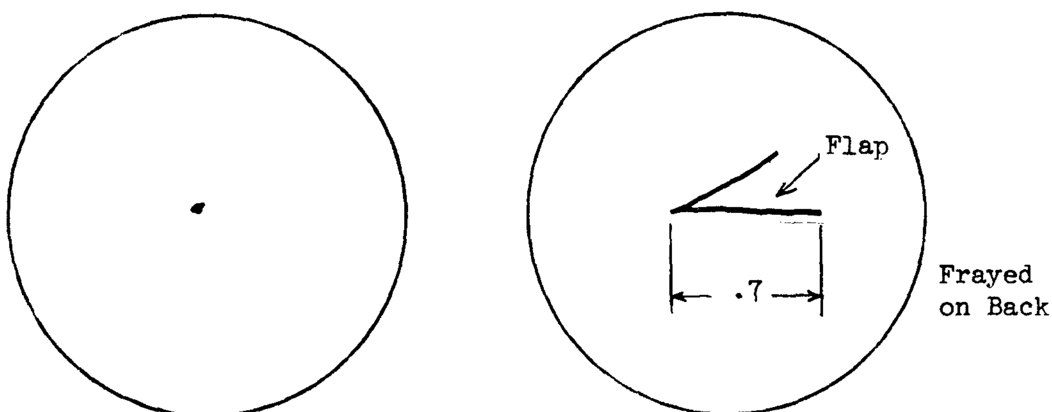
ROUND NUMBER T 76

ENTRANCE *EXIT



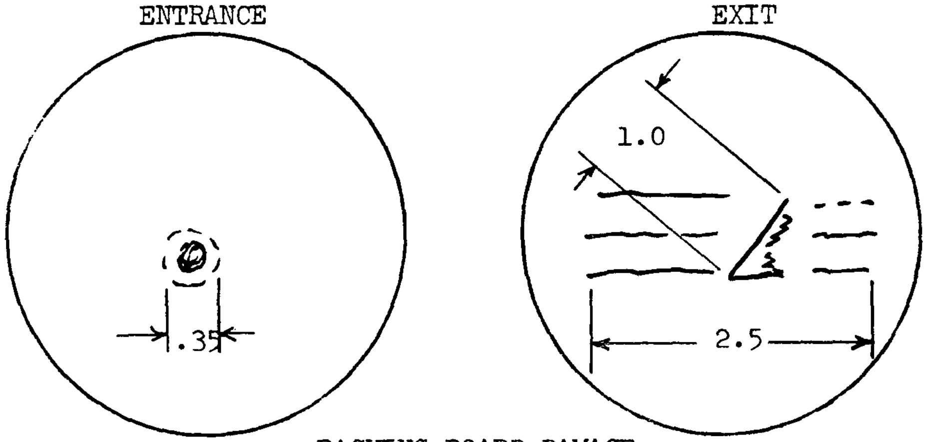
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 49 ROUND NUMBER T 77

DATE FIRED 1 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 (.080) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board Firestone B-2 (Cal. 50)

Composite --------------

Self Sealing Firestone F-1146 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 13 inches high.

The skin was cored and deflected inward. Also .3 petals occurred. The backing board was frayed the size of the projectile. The self-sealing material sealed dry immediately, but a vacuum was pulled in the tank by the exit failure immediately.

Exit: Tumbled 14 inches high.

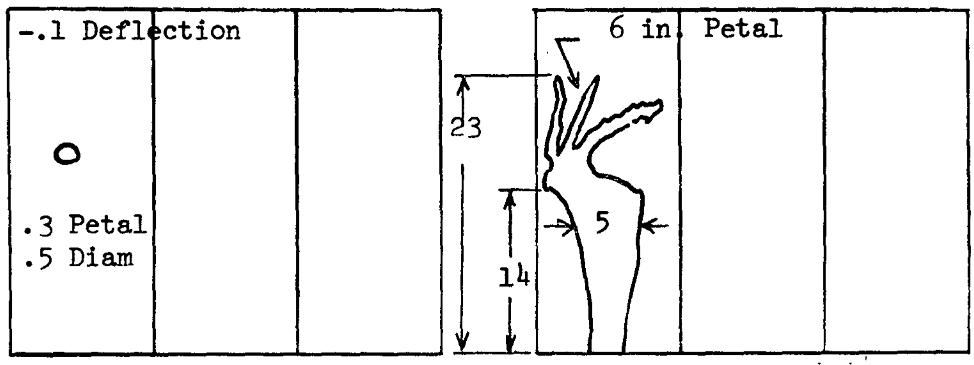
The skin failed top to bottom. The backing board split out as shown. The self-sealing material was slit, with the wound misaligned. Also the sealant was not activated. The edge of the material was torn approximately 12 inches long. The skin was badly cored and petaled.

Had to replace the complete rear panel combination to continue test. Leakage 4-5 gallon/minute at 0 pressure. Round struck steel support angle with a glancing flow.

BLOCK NUMBER B 49

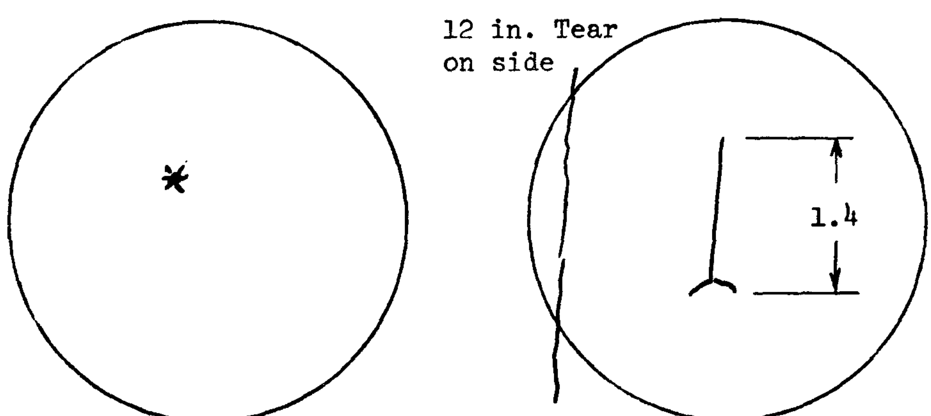
ROUND NUMBER T 77

ENTRANCE *EXIT



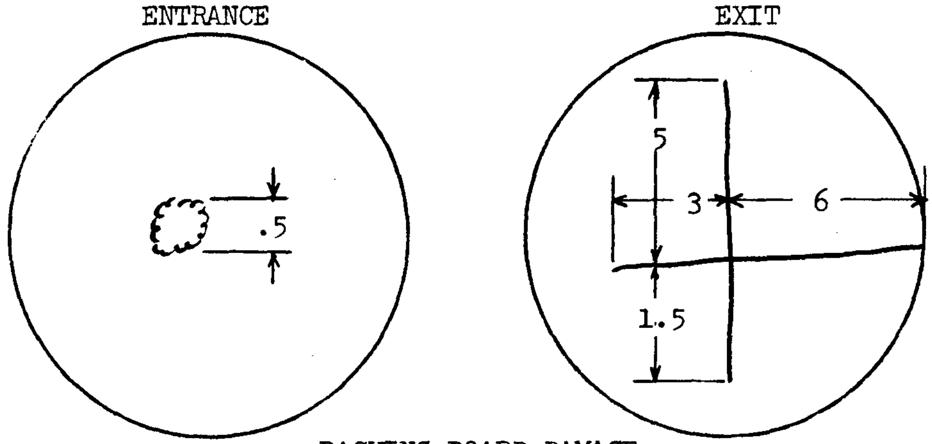
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 53.1 ROUND NUMBER T 78

DATE FIRED 1 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Whiffle balls full

Skin Material 6061-T6 (.080) Front only Skin Gap .75 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2685 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-23 (Cal. 30)

Composite -------------

Self Sealing Goodyear Tire FTL-13 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

Entrance: Straight 6 inches high. 12 inches fuel head.

The skin was cored and petaled (both inward and outward). The backing board frayed the size of the projectile. The self-sealing material sealed with only a trace of fuel on the outside surface.

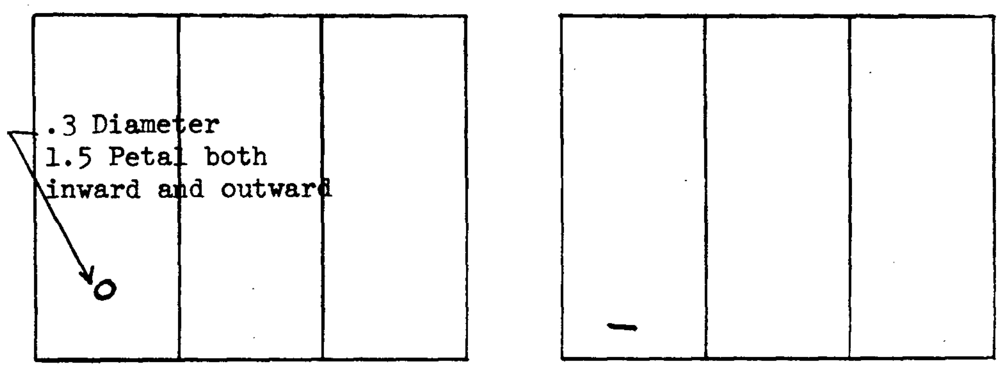
Exit: Partially tumbled. 1.5 inches high. 16.5 fuel head.

No skin installed. The backing board frayed badly but did maintain some support. The self-sealing material slit and was misaligned. Leakage was 1-2 gallon/minute at 2 psi. No possible seal. Leakage was at least twice that of Round T 76. At 0 pressure exit wound still sprayed fuel. On break down - examined the whiffle balls in the projectile path. Some were just punctured while others were exploded. There was no apparent effect of using the whiffle balls.

BLOCK NUMBER B 53.1

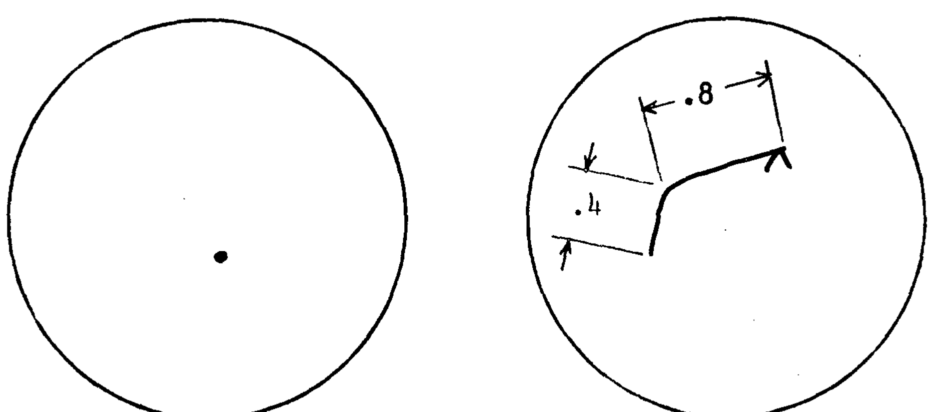
ROUND NUMBER T 78

ENTRANCE *EXIT



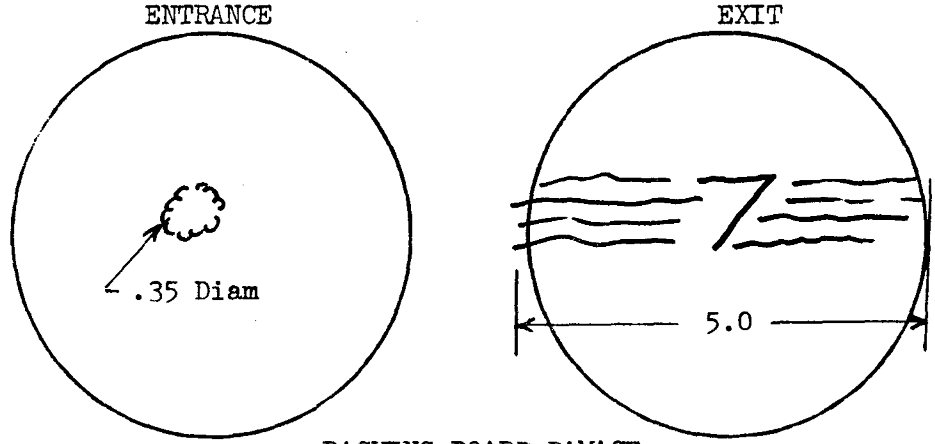
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 49.1 ROUND NUMBER T 79

DATE FIRED 1 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Orange foam

Skin Material 7075-T6 (.080) Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2878 Ft/Sec

MATERIAL:

Backing Board Firestone B-2 (Cal. 50)

Composite ------------

Self Sealing Firestone F-1146 (Cal. 50)

RESULTS:

Entrance Seal yes Exit Seal no

Entrance Cored no Exit Cored no

COMMENTS:

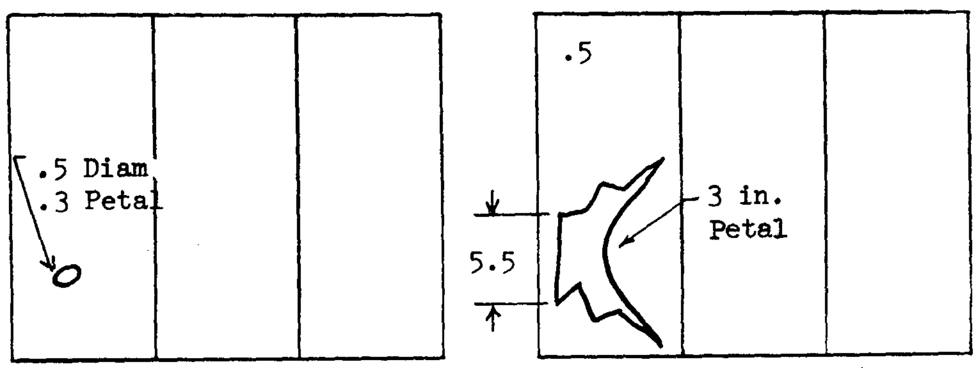
Entrance: Straight 7 inches high 11 inches fuel head. The skin was cored and petaled .3 inches high. The backing board was frayed the size of the projectile. The self-sealing sealed with only a trace of fuel leakage.

Exit: Tumbled 6 inches high
The skin was split and petaled. The backing board also split out. The self-sealing material was slit and the wound misaligned. However, the sealant was partially activated. The edge of the material was torn for approximately 5 inches. Leakage was 4-5 gallon/minute at 2 psi and 2-3 gallon/minute at 0 psi. Thus, the foam did help some in the self-sealing process. The round also struck the steel support angle.

BLOCK NUMBER B 49.1

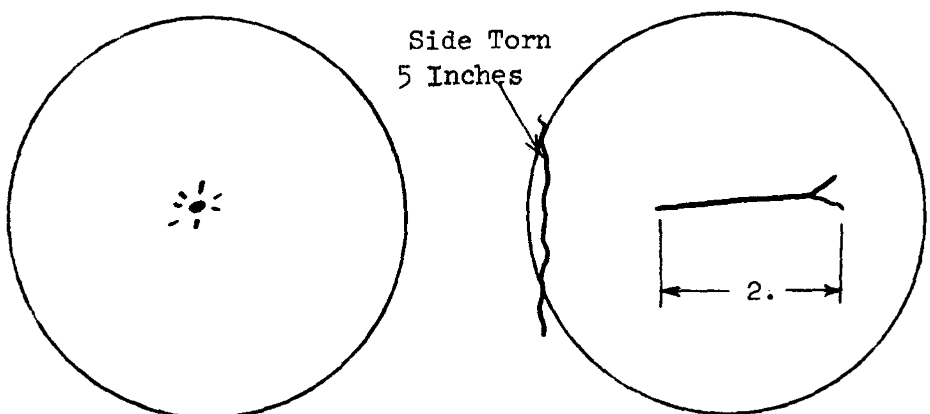
ROUND NUMBER T 79

ENTRANCE *EXIT



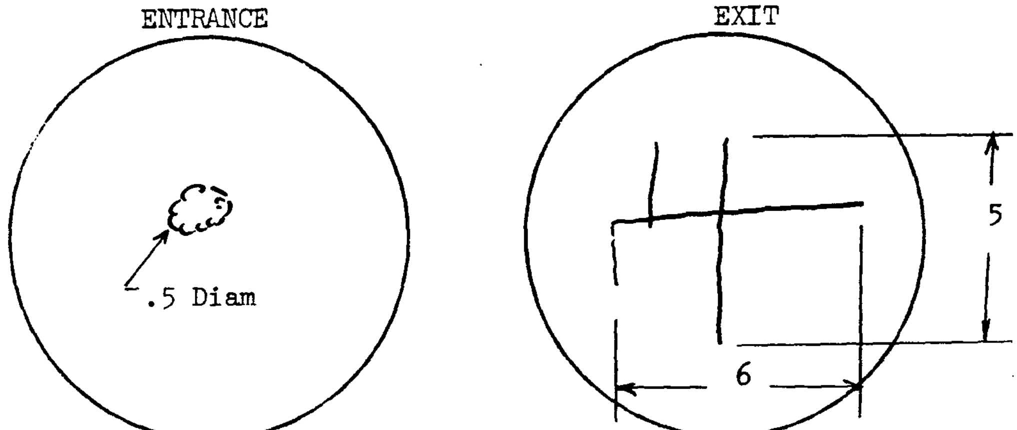
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 52 ROUND NUMBER T 80

DATE FIRED 5 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type AP Entry Straight

Velocity 2516 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-61 (Cal. 50)

Composite -------------

Self Sealing Firestone 1316-3 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

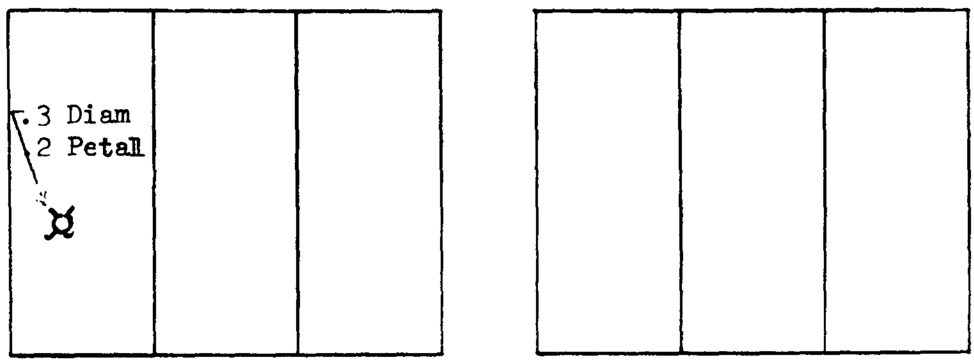
Entrance: 11.5 inches high straight 6.5 inches fuel head. The skin was cored with a few cracks (small). The backing board was frayed the size of the projectile. The self-sealing sealed dry with no trace of fuel leakage.

Exit: No skin installed. tumbled exit. 14 inches high - 4 inches fuel head. The backing board was frayed considerably but the cross grain construction did not lose much support. The self-sealing wound seeped for 1 minute 15 seconds and had a good seal in 1 minute 45 seconds at 2 psi pressure.

BLOCK NUMBER B 52

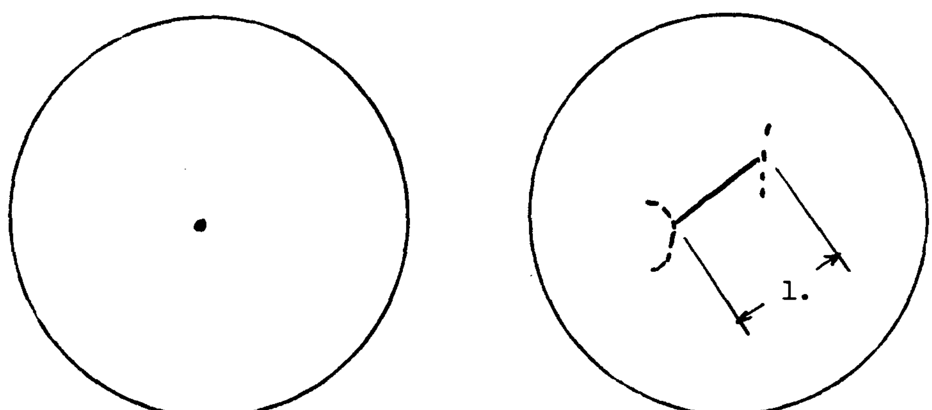
ROUND NUMBER T 80

ENTRANCE *EXIT



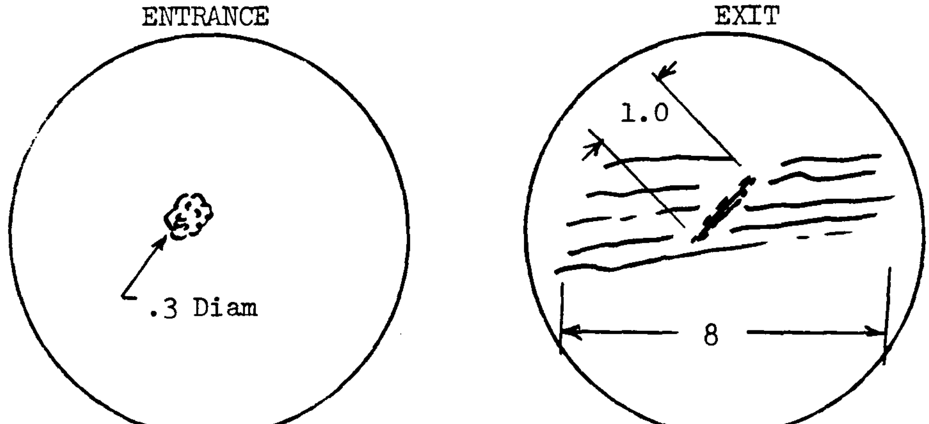
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 52 ROUND NUMBER T 81

DATE FIRED 5 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 (.040) Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity ---------- Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-61 (Cal. 50)

Composite -------------

Self Sealing Firestone 1316-3 (Cal. 30)

RESULTS:

Entrance Seal yes — Exit Seal **No exit**

Entrance Cored no — Exit Cored **N.A.**

COMMENTS:

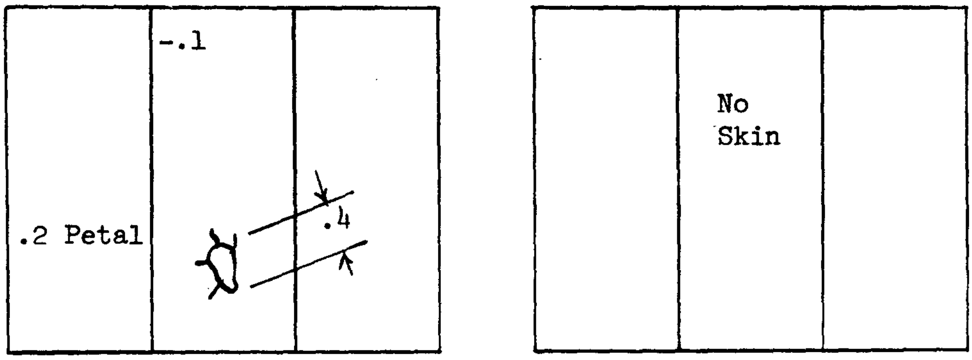
Entrance: Over tumbled and **base forward 7.5 inches high. 10.5 in. fuel** head. The skin was cored and cracked with inward deflections. The backing board was frayed the size of projectile 1/3 tumbled. The self-sealing material sealed immediately dry but became damp after 4 minutes. The **pressure** was reduced to zero at 3 minutes.

Exit: None. No damage observed.

BLOCK NUMBER B 52

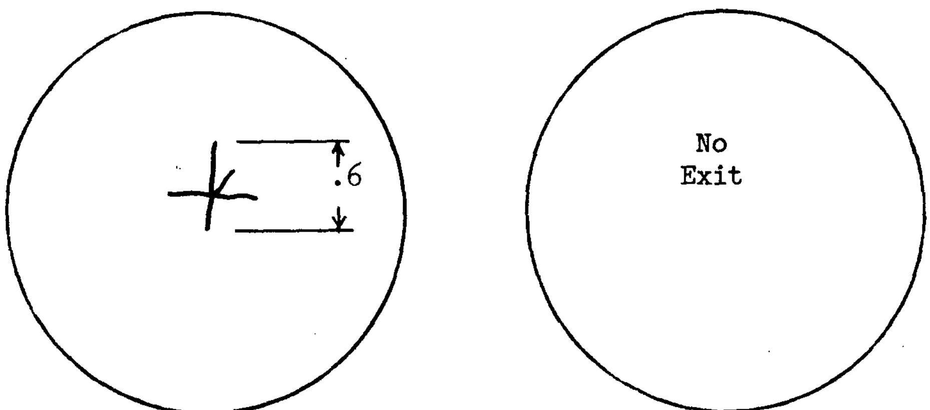
ROUND NUMBER T 81

ENTRANCE *EXIT



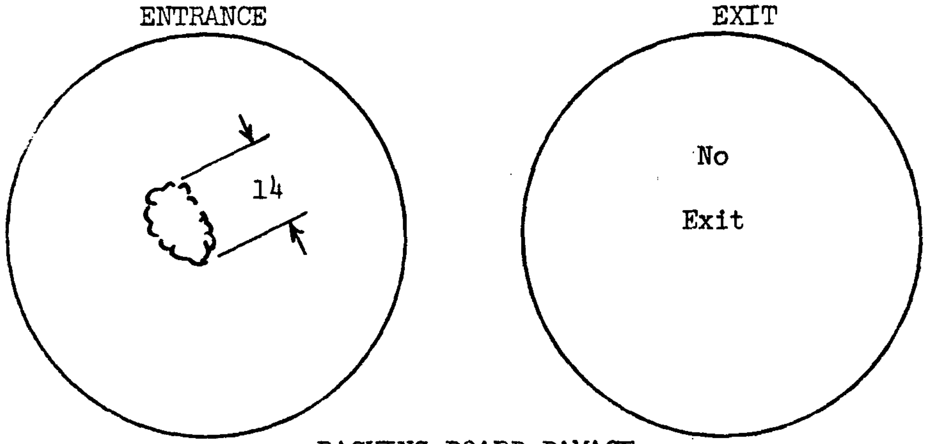
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 52 ROUND NUMBER T 82

DATE FIRED 5 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling None

Skin Material 7075-T6 (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type AP Entry Tumbled

Velocity ------ Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-61 (Cal. 50)

Composite ----------

Self Sealing Firestone 1316-3 (Cal. 30)

RESULTS:

Entrance Seal yes — Exit Seal No exit

Entrance Cored no — Exit Cored N.A.

COMMENTS:

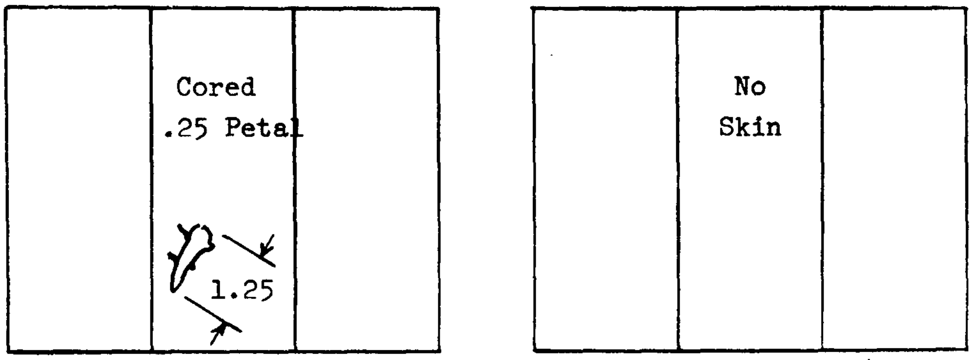
Entrance:
Fully tumbled 13.5 inches below fuel surface.
Saw flash on skin as entrance occurred. The skin was cored and petaled .25 high. The backing board was only frayed to the size of projectile. The self-sealing sealed damp immediately and dried when the pressure was reduced to zero after 3 minutes. Only leakage was a few drops.

Exit: None

BLOCK NUMBER B 52

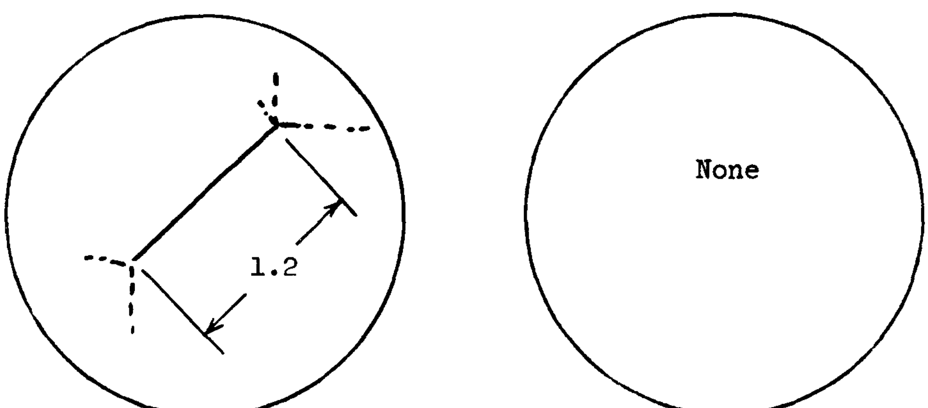
ROUND NUMBER T 82

ENTRANCE *EXIT



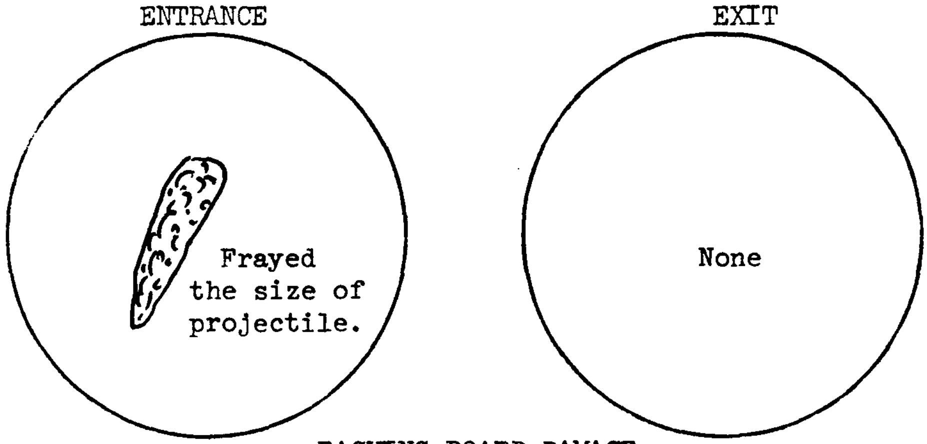
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 52.1 ROUND NUMBER T 83

DATE FIRED 5 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Orange Foam

Skin Material 7075-T6 (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 30 Type API Entry Straight

Velocity 2667 (Before striker plate) Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-61 (Cal. 50)

Composite --------

Self Sealing Firestone 1316-3 (Cal. 50)

RESULTS:

Entrance Seal yes   Exit Seal no exit

Entrance Cored no   Exit Cored N.A.

COMMENTS:

Entrance:

Actual entrance was fully tumbled 10 inches below the fuel surface. The Round struck the striker plate (7075-T6 .125 thick aluminum) and then tumbled.

The skin was cored and petaled. (Some signs of burning)

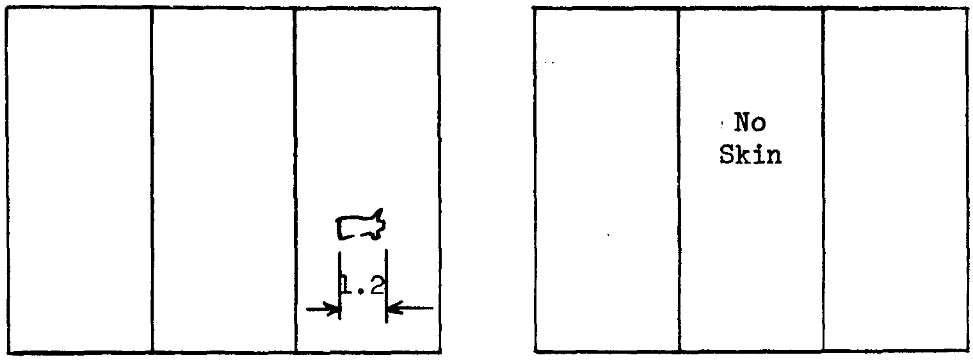
The backing board was frayed the size of tumbled projectile. The self-sealing material sealed damp immediately and sealed dry at 3 minutes when the pressure was reduced to zero. The leakage was only a few drops. Heard a hissing sound just after the projectile entered the cell probably from the incendiary portion of the projectile.

Exit: None

BLOCK NUMBER B 52.1

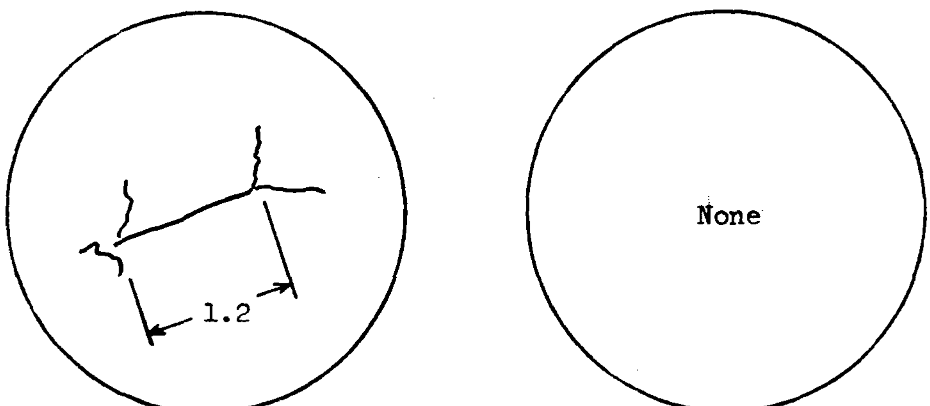
ROUND NUMBER T 83

ENTRANCE *EXIT



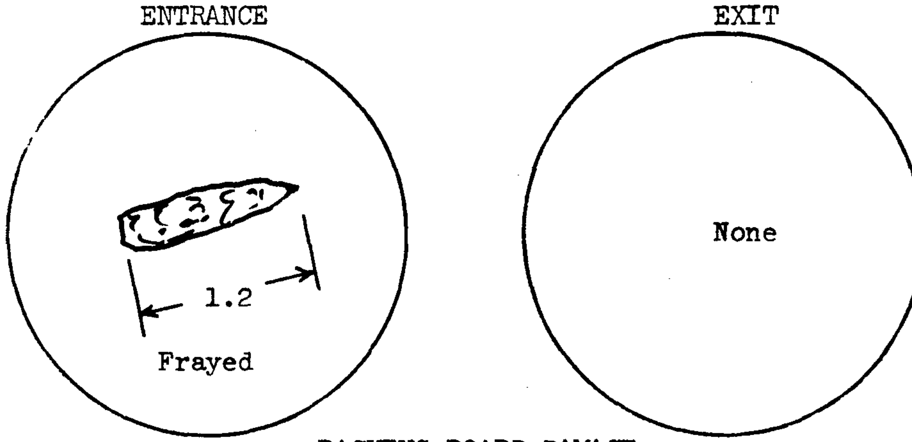
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 52.2 ROUND NUMBER T 84

DATE FIRED 5 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Orange Foam

Skin Material 7075-T6 (.040) Front only Skin Gap .25 in.

PROJECTILE:

Caliber 50 Type AP Entry Straight

Velocity 2857 Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN 2-61 (Cal. 50)

Composite –

Self Sealing Firestone 1316-3 (Cal. 30)

RESULTS:

Entrance Seal yes Exit Seal yes

Entrance Cored no Exit Cored no

COMMENTS:

Entrance:

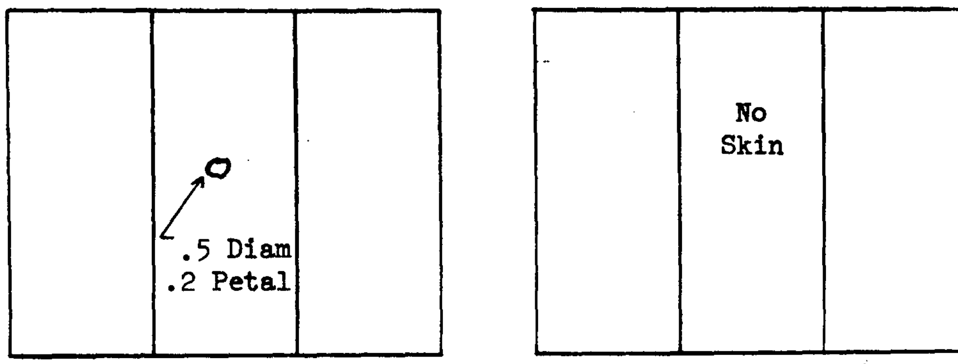
The entrance was straight and 4.5 inches below the fuel surface. The skin was cored .5 inches diameter and petaled .2 inches. The backing board was frayed and cored diameter of projectile. The self-sealing sealed dry immediately with only a trace of fuel leakage.

Exit:

The exit was straight but base forward. No skin was installed. The backing board frayed diameter of projectile and cracked to the supports. The self-sealing material sealed with only a seepage for 1 minute at 2 psi.

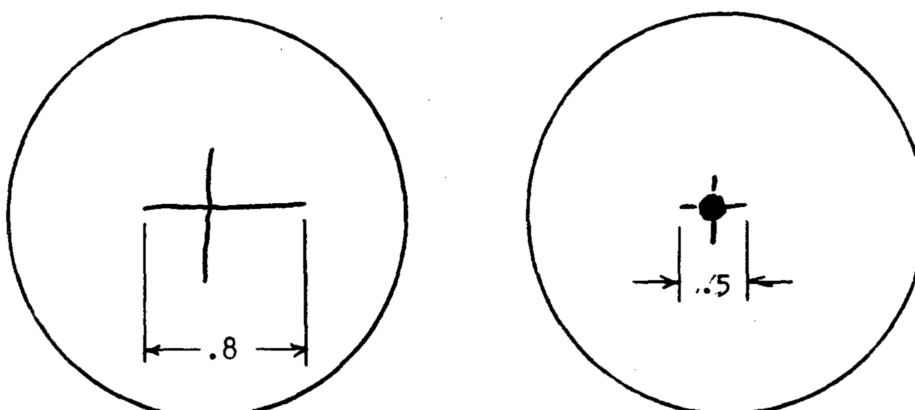
BLOCK NUMBER B 52.2
ROUND NUMBER T 84

ENTRANCE *EXIT



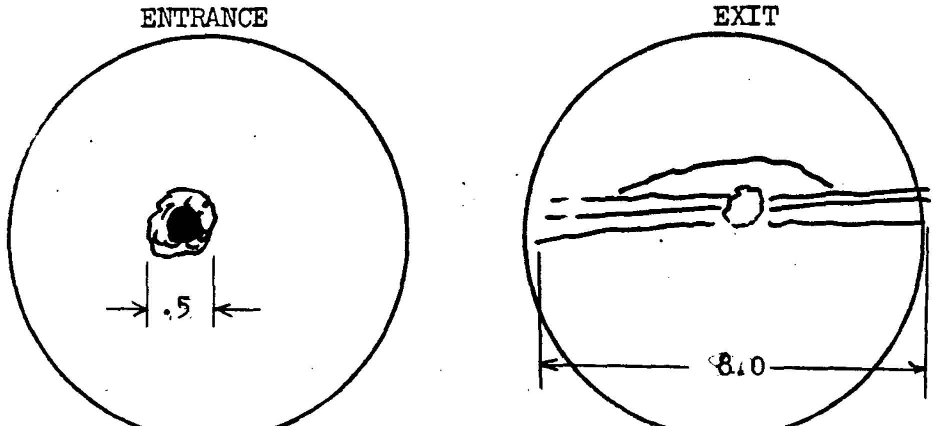
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE EXIT



TANK DAMAGE

ENTRANCE EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

BLOCK B 52.3 ROUND NUMBER T85

DATE FIRED 5 March 1968

TANK CONDITION:

Nitrogen Pressure 2 Psi; Baffling Orange Foam

Skin Material 7075-T6 (.040) Front only Skin Gap .25

PROJECTILE:

Caliber 50 Type API Entry Straight

Velocity --- Ft/Sec

MATERIAL:

Backing Board Air Logistics 700 SI EN2-61 (Cal. 50)

Composite ---

Self Sealing Firestone 1316-3 (Cal. 30)

RESULTS:

Entrance Seal no Exit Seal yes

Entrance Cored yes Exit Cored no

COMMENTS:

Entrance: Strike plate was .125 7075-T6 alum. plate spaced 18 in. away. Partial tumbled 8 in. below the fuel surface. The backing board frayed and cored badly. The self-sealing material cored and frayed badly. No Seal.

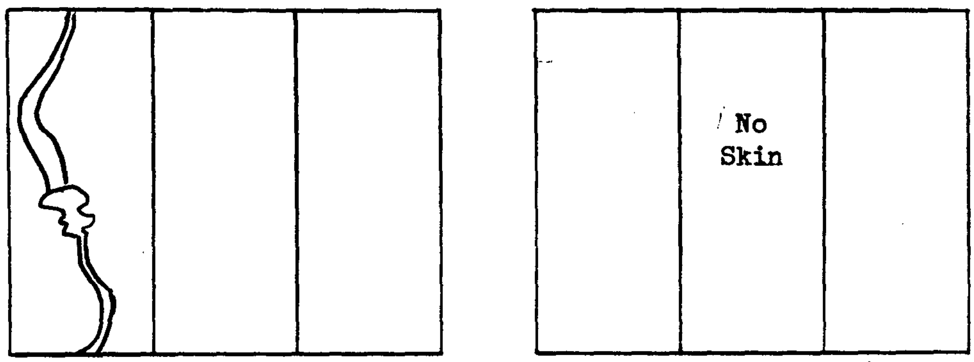
Exit: No skin installed. Tumbled exit 12 in. below the fuel surface. The backing board slit and frayed badly. The self-sealing sealed with very little leakage.

The box caught fire on the front surface upon impact. Fireman standing by extinguished the fire in 2.5 minutes. All the fire was on the external surfaces of the box and the major part on the front. Fire did spread to the back but was small and was not shown on the high speed movie. When the fire was out fuel was still above the wound.

BLOCK NUMBER B 52.3

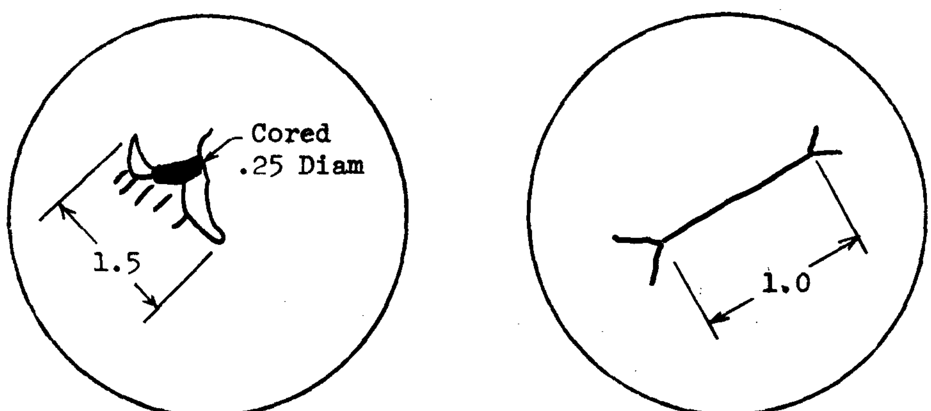
ROUND NUMBER T 85

ENTRANCE | *EXIT



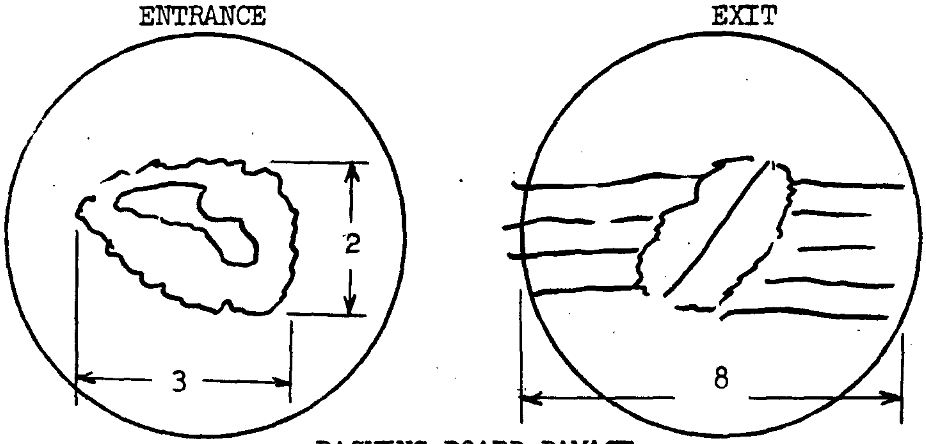
SKIN PANEL DAMAGE AND DEFLECTIONS

ENTRANCE | EXIT



TANK DAMAGE

ENTRANCE | EXIT



BACKING BOARD DAMAGE

* Exit conditions are shown as they would be seen from inside the tank
All dimensions are reported in inches.

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Directorate of Laboratories, Air Force Materials Laboratory (MAAE), Wright-Patterson Air Force Base, Ohio

13. ABSTRACT

This report describes the work done in a program to investigate available methods of protection of aircraft fluid systems from ballistic damage. Primary emphasis in this study was placed upon the protection of aircraft fuel tanks through the use of self-sealing fuel tank materials. A number of protection materials were selected and subjected to gunfire testing with .30 and .50 caliber projectiles. Significant conclusions of the program are as follows:

a. Internal tank pressures reduce probability of sealing.

b. Hydraulic ram pressure induces significant structural damage, thereby reducing probability of sealing exit wounds.

c. Petaling of skins in intimate contact with tank material had little or no effect on sealing of entrance wounds.

d. Existing materials can provide satisfactory protection when properly utilized.

e. Several new materials were tested which show evidence of potential application, particularly backing boards.

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Aircraft fuel tanks Self-sealing fuel tanks Passive defense of fluid systems Ballistic projectile protection Aircraft fluid systems						